Jeffrey S. Green
Assistant Regional Director
USDA-APHIS-
Animal Damage Control
Lakewood, Colorado 80228

F. Robert Henderson
Extension Specialist
Animal Damage Control
Kansas State University
Manhattan, Kansas 66506-1600

Mark D. Collinge
State Director
USDA-APHIS-
Animal Damage Control
Boise, Idaho 83705

COYOTES

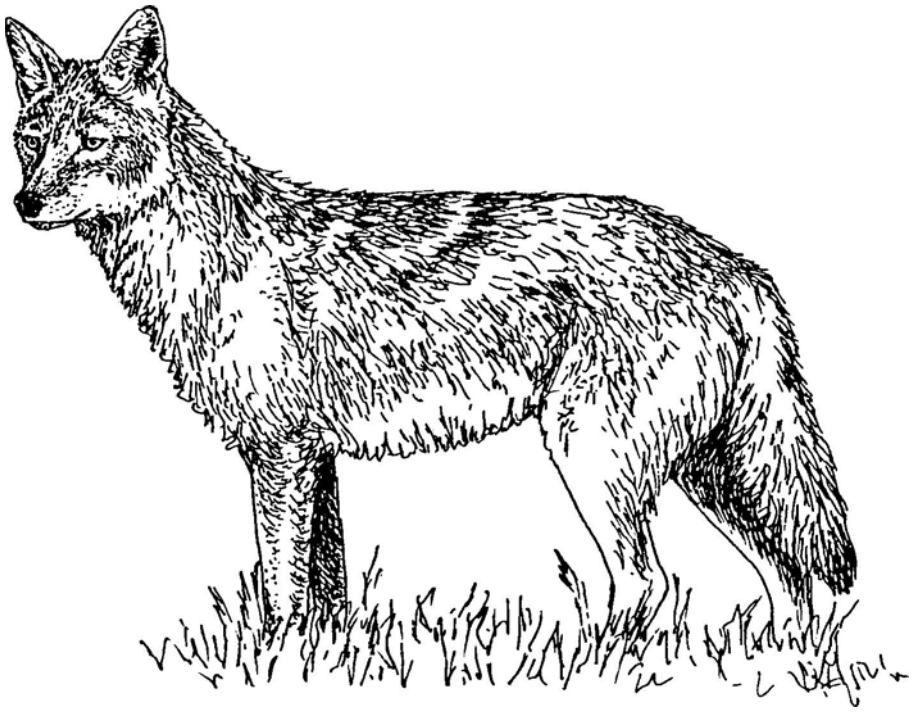

Fig. 1. Coyote, *Canis latrans*

Damage Prevention and Control Methods

Exclusion

Produce livestock in confinement.

Herd livestock into pens at night.

Exclusion fences (net-wire and/or electric), properly constructed and maintained, can aid significantly in reducing predation.

Cultural Methods and Habitat Modification

Select pastures that have a lower incidence of predation to reduce exposure of livestock to predation.

Herding of livestock generally reduces predation due to human presence during the herding period.

Change lambing, kidding, and calving seasons.

Shed lambing, kidding, and calving usually reduce coyote predation.

Remove carrion to help limit coyote populations.

Frightening Agents and Repellents

Guarding dogs: Some dogs have significantly reduced coyote predation.

Donkeys and llamas: Some are aggressive toward canines and have reduced coyote predation.

Sonic and visual repellents: Strobe lights, sirens, propane cannons, and others have reduced predation on both sheep and calves.

Chemical odor and taste repellents: None have shown sufficient effectiveness to be registered for use.

Trapping

Body-gripping traps are illegal for use in commercial fur or recreational application in California (see regulations).

There are zones throughout California where the use of Conibear-type traps and snares, except those totally submerged, and deadfall traps are prohibited for the protection of the San Joaquin kit fox and Sierra Nevada red fox (see regulations).

PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994
Cooperative Extension Division
Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln
United States Department of Agriculture
Animal and Plant Health Inspection Service
Animal Damage Control
Great Plains Agricultural Council
Wildlife Committee

Shooting

Shooting from the ground is effective.

Use rabbit distress calls or mimic howling or other coyote sounds to bring coyotes within shooting distance.

Hunting with dogs is effective for trailing coyotes from kill sites, locating dens, running coyotes, and assisting with calling.

Other Methods

Denning: Remove adult coyotes and/or their young from dens.

Identification

In body form and size, the coyote (*Canis latrans*) resembles a small collie dog, with erect pointed ears, slender muzzle, and a bushy tail (Fig. 1). Coyotes are predominantly brownish gray in color with a light gray to cream-colored belly. Color varies greatly, however, from nearly black to red or nearly white in some individuals and local populations. Most have dark or black guard hairs over their back and tail. In western states, typical adult males weigh from 25 to 45 pounds (11 to 16 kg) and females from 22 to 35 pounds (10 to 14 kg). In the East, many coyotes are larger than their western counterparts, with males averaging about 45 pounds (14 kg) and females about 30 pounds (13 kg).

Coyote-dog and coyote-wolf hybrids exist in some areas and may vary greatly from typical coyotes in size, color, and appearance. Also, coyotes in the New England states may differ in color from typical western coyotes. Many are black, and some are reddish. These colorations may partially be due to past hybridization with dogs and wolves. True wolves are also present in some areas of coyote range, particularly in Canada, Alaska, Montana, northern Minnesota, Wisconsin, and Michigan. Relatively few wolves remain in the southern United States and Mexico.

Range

Historically, coyotes were most common on the Great Plains of North America. They have since extended their range from Central America to the Arctic, including all of the United States (except Hawaii), Canada, and Mexico.

Habitat

Many references indicate that coyotes were originally found in relatively open habitats, particularly the grasslands and sparsely wooded areas of the western United States. Whether or not this was true, coyotes have adapted to and now exist in virtually every type of habitat, arctic to tropic, in North America. Coyotes live in deserts, swamps, tundra, grasslands, brush, dense forests, from below sea level to high mountain ranges, and at all intermediate altitudes. High densities of coyotes also appear in the suburbs of Los Angeles, Pasadena, Phoenix, and other western cities.

Food Habits

Coyotes often include many items in their diet. Rabbits top the list of their dietary components. Carrion, rodents, ungulates (usually fawns), insects (such as grasshoppers), as well as livestock and poultry, are also consumed. Coyotes readily eat fruits such as watermelons, berries, and other vegetative matter when they are available. In some areas coyotes feed on human refuse at dump sites and take pets (cats and small dogs).

Coyotes are opportunistic and generally take prey that is the easiest to secure. Among larger wild animals, coyotes tend to kill young, inexperienced animals, as well as old, sick, or weakened individuals. With domestic animals, coyotes are capable of catching and killing healthy, young, and in some instances, adult prey. Prey selection is based on opportunity and a myriad of behavioral cues. Strong, healthy lambs are often taken from a flock by a coyote even though smaller, weaker lambs are also present. Usually, the stronger lamb is on the periphery and is more active, making it more prone to attack than a weaker lamb that is at the center of the flock and relatively immobile.

Coyote predation on livestock is generally more severe during early spring and summer than in winter for two reasons. First, sheep and cows are usually under more intensive management during winter, either in feedlots or in pastures that are close to human activity, thus reducing the opportunity for coyotes to take livestock. Second, predators bear young in the spring and raise them through the summer, a process that demands increased nutritional input, for both the whelping and nursing mother and the growing young. This increased demand corresponds to the time when young sheep or beef calves are on pastures or rangeland and are most vulnerable to attack. Coyote predation also may increase during fall when young coyotes disperse from their home ranges and establish new territories.

General Biology, Reproduction, and Behavior

Coyotes are most active at night and during early morning hours (especially where human activity occurs), and during hot summer weather. Where there is minimal human interference and during cool weather, they may be active throughout the day.

Coyotes bed in sheltered areas but do not generally use dens except when raising young. They may seek shelter underground during severe weather or when closely pursued. Their physical abilities include good eyesight and

hearing and a keen sense of smell. Documented recoveries from severe injuries are indicative of coyotes' physical endurance. Although not as fleet as greyhound dogs, coyotes have been measured at speeds of up to 40 miles per hour (64 km/hr) and can sustain slower speeds for several miles (km).

Distemper, hepatitis, parvo virus, and mange (caused by parasitic mites) are among the most common coyote diseases. Rabies and tularemia also occur and may be transmitted to other animals and humans. Coyotes harbor numerous parasites including mites, ticks, fleas, worms, and flukes. Mortality is highest during the first year of life, and few survive for more than 10 to 12 years in the wild. Human activity is often the greatest single cause of coyote mortality.

Coyotes usually breed in February and March, producing litters about 9 weeks (60 to 63 days) later in April and May. Females sometimes breed during the winter following their birth, particularly if food is plentiful. Average litter size is 5 to 7 pups, although up to 13 in a litter has been reported. More than one litter may be found in a single den; at times these may be from females mated to a single male. As noted earlier, coyotes are capable of hybridizing with dogs and wolves, but reproductive dysynchrony and behaviors generally make it unlikely. Hybrids are fertile, although their breeding seasons do not usually correspond to those of coyotes.

Coyote dens are found in steep banks, rock crevices, sinkholes, and underbrush, as well as in open areas. Usually their dens are in areas selected for protective concealment. Den sites are typically located less than a mile (km) from water, but may occasionally be much farther away. Coyotes will often dig out and enlarge holes dug by smaller burrowing animals. Dens vary from a few feet (1 m) to 50 feet (15 m) and may have several openings.

Both adult male and female coyotes hunt and bring food to their young for several weeks. Other adults associated with the denning pair may also help in feeding and caring for the young. Coyotes commonly hunt as singles or pairs; extensive travel is common in their hunting forays. They will hunt in the same area regularly, however, if food is plentiful. They occasionally bury food remains for later use.

Pups begin emerging from their den by 3 weeks of age, and within 2 months they follow adults to large prey or carrion. Pups normally are weaned by 6 weeks of age and frequently are moved to larger quarters such as dense brush patches and/or sinkholes along water courses. The adults and pups usually remain together until late summer or fall when pups become independent. Occasionally pups are found in groups until the breeding season begins.

Coyotes are successful at surviving and even flourishing in the presence of people because of their adaptable behavior and social system. They typically display increased reproduction and immigration in response to human-induced population reduction.

Damage and Damage Identification

Coyotes can cause damage to a variety of resources, including livestock, poultry, and crops such as watermelons. They sometimes prey on pets and are a threat to public health and safety when they frequent airport runways and residential areas, and act as carriers of rabies. Usually, the primary concern regarding coyotes is predation on livestock, mainly sheep and lambs. Predation will be the focus of the following discussion.

Since coyotes frequently scavenge on livestock carcasses, the mere presence of coyote tracks or droppings near a carcass is not sufficient evidence that predation has taken place. Other evidence around the site and on the carcass must be carefully examined to aid in determining the cause of death. Signs of a struggle may be evident. These may include scrapes or drag marks on the ground, broken vegetation, or blood in various places around the site. The quantity of sheep or calf remains left after a kill vary widely depending on how recently the kill was made, the size of the animal killed, the weather, and the number and species of predators that fed on the animal.

One key in determining whether a sheep or calf was killed by a predator is the presence or absence of subcutaneous (just under the skin) hemorrhage at the point of attack. Bites to a dead animal will not produce hemorrhage, but bites to a live animal will. If enough of the sheep carcass remains, carefully skin out the neck and head to observe tooth punctures and hemorrhage around the punctures. Talon punctures from large birds of prey will also cause hemorrhage, but the location of these is usually at the top of the head, neck, or back. This procedure becomes less indicative of predation as the age of the carcass increases or if the remains are scanty or scattered.

Coyotes, foxes, mountain lions, and bobcats usually feed on a carcass at the flanks or behind the ribs and first consume the liver, heart, lungs, and other viscera. Mountain lions often cover a carcass with debris after feeding on it. Bears generally prefer meat to viscera and often eat first the udder from lactating ewes. Eagles skin out carcasses on larger animals and leave much of the skeleton intact. With smaller animals such as lambs, eagles may bite off and swallow the ribs. Feathers and "whitewash" (droppings) are usually present where an eagle has fed.

Coyotes may kill more than one animal in a single episode, but often will only feed on one of the animals. Coyotes typically attack sheep at the throat, but young or inexperienced coyotes may attack any part of the body. Coyotes usually kill calves by eating into the anus or abdominal area.

Dogs generally do not kill sheep or calves for food and are relatively indiscriminate in how and where they attack. Sometimes, however, it is difficult to differentiate between dog and coyote kills without also looking at other sign, such as size of tracks (Fig. 2) and spacing and size of canine

tooth punctures. Coyote tracks tend to be more oval-shaped and compact than those of common dogs. Nail marks are less prominent and the tracks tend to follow a straight line more closely than those of dogs. The average coyote's stride at a trot is 16 to 18 inches (41 to 46 cm), which is typically longer than that of a dog of similar size and weight. Generally, dogs attack and rip the flanks, hind quarters, and head, and may chew ears. The sheep are sometimes still alive but may be severely wounded.

Accurately determining whether or not predation occurred and, if so, by what species, requires a considerable amount of knowledge and experience. Evidence must be gathered, pieced together, and then evaluated in light of the predators that are in the area, the time of day, the season of the year, and numerous other factors. Sometimes even experts are unable to confirm the cause of death, and it may be necessary to rely on circumstantial information.

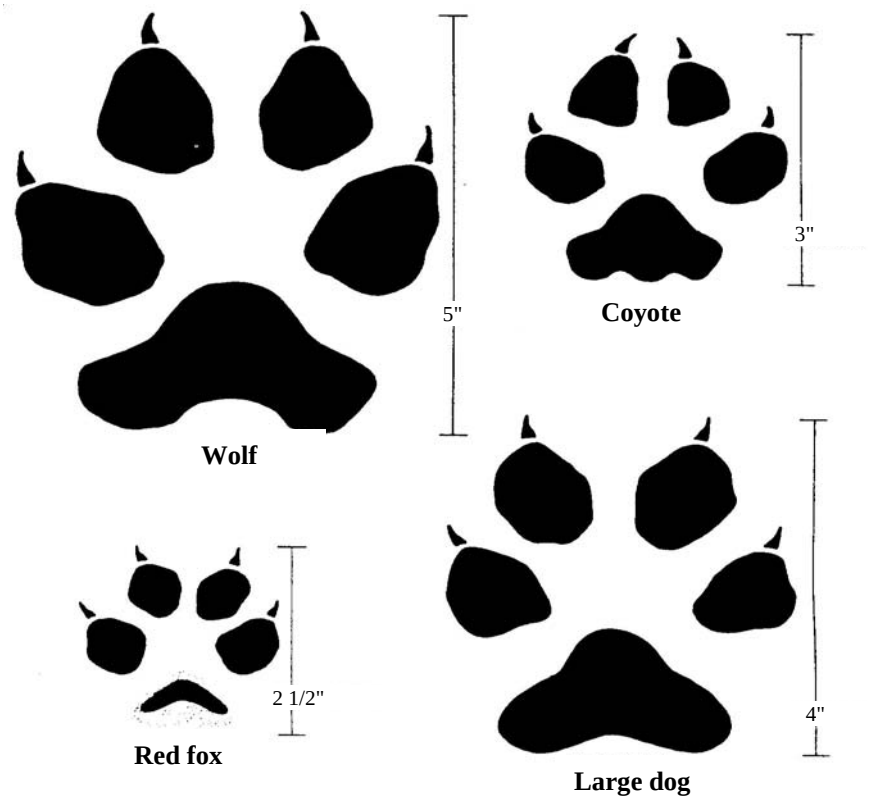

Fig. 2. Footprints of canid predators

Legal Status

In California, the coyote is designated as a nongame mammal. See California statutes and regulations regarding the take of furbearing and nongame mammals.

Damage Prevention and Control Methods

For managing coyote damage, a variety of control methods must be available since no single method is effective in every situation. Success usually involves an integrated approach, combining good husbandry practices with effective control methods for short periods of time. Regardless of the means used to stop damage, the focus should be on damage prevention and control rather than elimination of coyotes. It is neither wise nor practical to kill all coyotes. It is important to try to prevent coyotes from killing calves or sheep for the first time. Once a coyote has killed livestock, it will probably continue to do so if given the opportunity. Equally important is taking action as quickly as possible to stop coyotes from killing after they start.

Exclusion

Most coyotes readily cross over, under, or through conventional livestock fences. A coyote's response to a fence is influenced by various factors, including the coyote's experience and motivation for crossing the fence. Total exclusion of all coyotes by fencing, especially from large areas, is highly unlikely since some eventually learn to either dig deeper or climb higher to defeat a fence. Good fences, however, can be important in reducing predation, as well as increasing the effectiveness of other damage control methods (such as snares, traps, or guarding animals). Recent developments in fencing equipment and design have made this technique an effective and economically practical method for protecting sheep from predation under some grazing conditions. Exclusion fencing may be impractical in western range sheep ranching operations.

Net-Wire Fencing. Net fences in good repair will deter many coyotes from entering a pasture. Horizontal spacing of the mesh should be less than 6 inches (15 cm), and vertical spacing less than 4 inches (10 cm). Digging under a fence can be discouraged by placing a barbed wire at ground level or using a buried wire apron (often an expensive option). The fence should be about 5 1/2 feet (1.6 m) high to discourage coyotes from jumping over it. Climbing can usually be prevented by adding a charged wire at the top of the fence or installing a wire overhang.

Barrier fences with wire overhangs and buried wire aprons were tested in Oregon and found effective in keeping coyotes out of sheep pastures (Fig. 3).

The construction and materials for such fencing are usually expensive. Therefore, fences of this type are rarely used except around corrals, feedlots, or areas of temporary sheep confinement.

Electric Fencing. Electric fencing, used for years to manage livestock, has recently been revolutionized by the introduction of new energizers and new fence designs from Australia and New Zealand. The chargers, now also manufactured in the United States, have high output with low impedance, are resistant to grounding, present a minimal fire hazard, and are generally safe for livestock and humans. The fences are usually constructed of smooth, high-tensile wire stretched to a tension of 200 to 300 pounds (90 to 135 kg). The original design of electric fences for controlling predation consisted of multiple, alternately charged and grounded wires, with a charged trip wire installed just above ground level about 8 inches (20 cm) outside the main fence to discourage digging. Many recent designs have every wire charged.

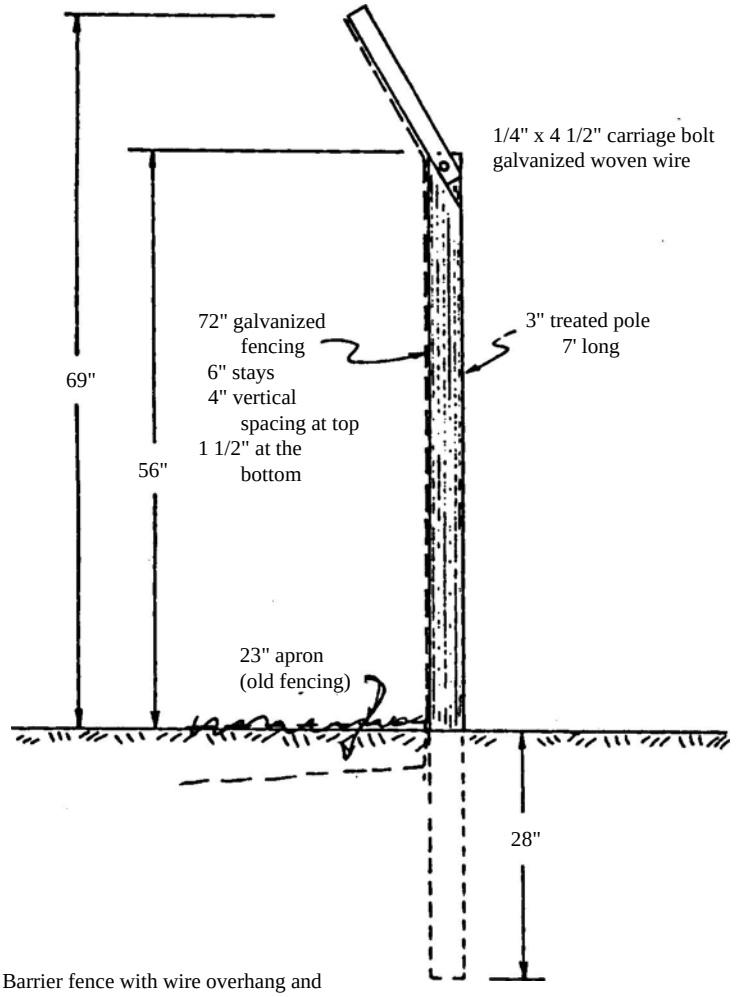

Fig. 3. Barrier fence with wire overhang and buried apron.

The number of spacings between wires varies considerably. A fence of 13 strands gave complete protection to sheep from coyote predation in tests at the USDA's US Sheep Experiment Station (Fig. 4). Other designs of fewer wires were effective in some studies, ineffective in others.

The amount of labor and installation techniques required vary with each type of fencing. High-tensile wire fences require adequate bracing at corners and over long spans. Electric fencing is easiest to install on flat, even terrain. Labor to install a high-tensile electric fence may be 40% to 50% less than for a conventional livestock fence.

Labor to keep electric fencing functional can be significant. Tension of the wires must be maintained, excessive vegetation under the fence must be removed to prevent grounding, damage from livestock and wildlife must be repaired, and the charger must be checked regularly to ensure that it is operational.

Coyotes and other predators occasionally become "trapped" inside electric fences. These animals receive a shock as they enter the pasture and subsequently avoid approaching the fence to escape. In some instances the captured predator may be easy to spot and remove from the pasture, but in others, particularly in large pastures with rough terrain, the animal may be difficult to remove.

Electric Modification of Existing Fences. The cost to completely replace old fences with new ones, whether conventional or electric, can be substantial. In instances where existing fencing is in reasonably good condition, the addition of one to several charged wires can significantly enhance the predator-deterring ability of the fence and its effectiveness for controlling livestock (Fig. 5). A charged trip wire placed 6 to 8 inches (15 to 230 cm) above the ground about 8 to 10 inches (20 to 25 cm) outside the fence is often effective in preventing coyotes from digging and crawling under. This single addition to an existing fence is often the most effective and economical way to fortify a fence against coyote passage.

If coyotes are climbing or jumping a fence, charged wires can be added to the top and at various intervals. These wires should be offset outside the fence. Fencing companies offer offset brackets to make installation relatively simple. The number of additional wires depends on the design of the original fence and the predicted habits of the predators.

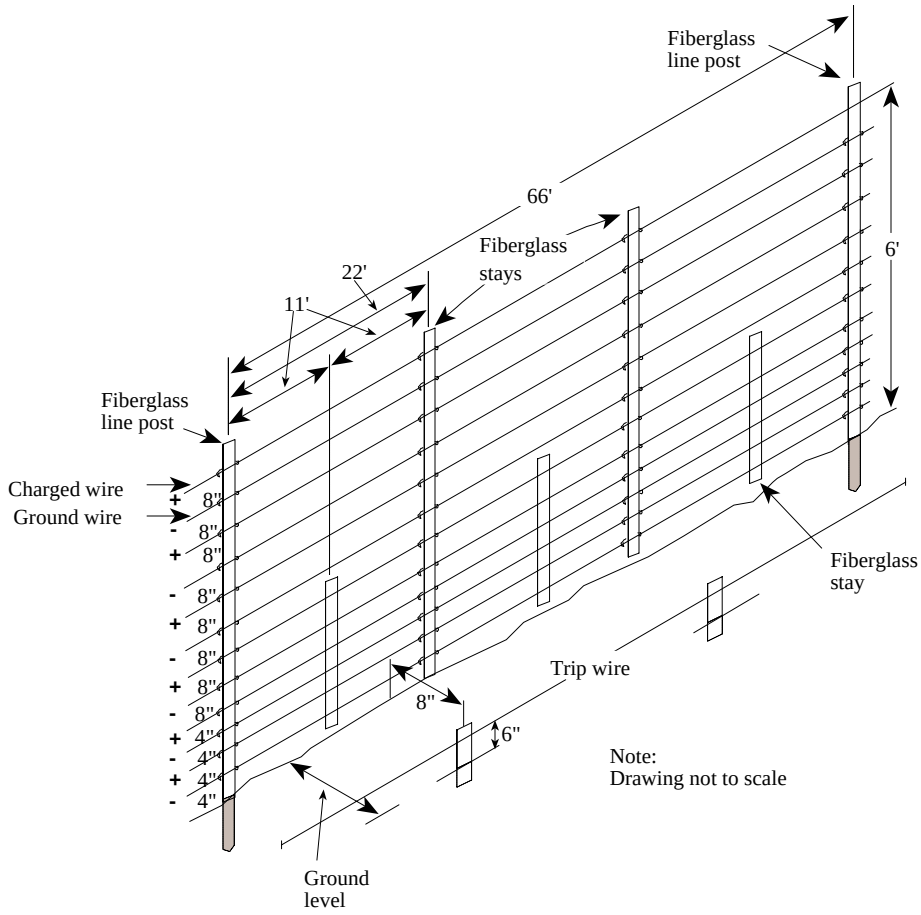

Fig. 4. High-tensile, electric, antipredator fence.

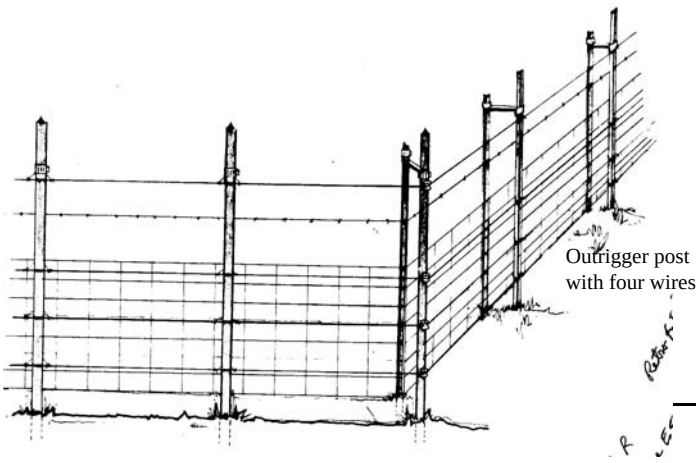

Fig. 5. Existing woven-wire livestock fence modified with electrified wire.

Portable Electric Fencing. The advent of safe, high-energy chargers has led to the development of a variety of portable electric fences. Most are constructed with thin strands of wire running through polyethylene twine or ribbon, commonly called polywire or polytape. The polywire is available in single and multiple wire rolls or as mesh fencing of various heights. It can be quickly and easily installed to serve as a temporary corral or to partition off pastures for controlled grazing.

Perhaps the biggest advantage of portable electric fencing is the ability to set up temporary pens to hold livestock at night or during other predator control activities. Portable fencing increases livestock management options to avoid places or periods of high predation risk. Range sheep that are not accustomed to being fenced, however, may be difficult to contain in a portable fence.

Fencing and Predation Management. The success of various types of fencing in keeping out predators has ranged from poor to excellent. Density and behavior of coyotes, terrain and vegetative conditions, availability of prey, size of pastures, season of the year, design of the fence, quality of construction, maintenance, and other factors all interplay in determining how effective a fence will be. Fencing is most likely to be cost-effective where the potential for predation is high, where there is potential for a high stocking rate, or where electric modification of existing fences can be used.

Fencing can be effective when incorporated with other means of predation control. For example, combined use of guarding dogs and fencing has achieved a greater degree of success than either method used alone. An electric fence may help keep a guarding dog in and coyotes out of a pasture. If an occasional coyote does pass through a fence, the guarding dog can keep it away from the livestock and alert the producer by barking.

Fencing can also be used to concentrate predator activity at specific places such as gateways, ravines, or other areas where the animals try to gain access. Traps and snares can often be set at strategic places along a fence to effectively capture predators. Smaller pastures are easier to keep free from predators than larger ones encompassing several square miles $(km)^2$.

Fencing is one of the most beneficial investments in predator damage control and livestock management where practical factors warrant its use.
As a final note, fences can pose problems for wildlife. Barrier fences in particular exclude not only predators, but also many other wildlife species. This fact should be considered where fencing intersects migration corridors for wildlife. Ungulates such as deer may attempt to jump fences, and they occasionally become entangled in the top wires.

Cultural Methods and Habitat Modification

At the present time, there are no documented differences in the vulnerability of various breeds of sheep to coyote or dog predation because there has been very little research in this area. Generally, breeds with stronger flocking behaviors are less vulnerable to predators.

A possible cause of increased coyote predation to beef cattle calves is the increased use of cattle dogs in herding. Cows herded by dogs may not be as willing to defend newborn calves from coyotes as those not accustomed to herding dogs.

Flock or Herd Health. Healthy sheep flocks and cow/calf herds have higher reproductive rates and lower overall death losses. Coyotes often prey on smaller lambs. Poor nutrition means weaker or smaller young, with a resultant increased potential for predation. Ewes or cows in good condition through proper nutrition will raise stronger young that may be less vulnerable to coyote predation.

Record Keeping. Good record-keeping and animal identification systems are invaluable in a livestock operation for several reasons. From the standpoint of coyote predation, records help producers identify loss patterns or trends to provide baseline data that will help determine what type and amount of coyote damage control is economically feasible. Records also aid in identifying critical problem areas that may require attention. They may show, for example, that losses to coyotes are high in a particular pasture in early summer, thus highlighting the need for preventive control in that area.

Counting sheep and calves regularly is important in large pastures or areas with heavy cover where dead livestock could remain unnoticed. It is not unusual for producers who do not regularly count their sheep to suffer fairly substantial losses before they realize there is a problem. Determining with certainty whether losses were due to coyotes or to other causes may become impossible.

Season and Location of Lambing or Calving. Both season and location of lambing and calving can significantly affect the severity of coyote predation on sheep or calves. The highest predation losses of sheep and calves typically occur from late spring through September due to the food requirements of coyote pups. In the Midwest and East, some lambing or calving occurs between October and December, whereas in most of the western states lambing or calving occurs between February and May. By changing to a fall lambing or calving program, some livestock producers have not only been able to diversify their marketing program, but have also avoided having a large number of young animals on hand during periods when coyote predation losses are typically highest.

Shortening lambing and calving periods by using synchronized or group breeding may reduce predation by producing a uniform lamb or calf crop, thus reducing exposure of small livestock to predation. Extra labor and facilities may be necessary, however, when birthing within a concentrated period. Some producers practice early weaning and do not allow young to go to large pastures, thus reducing the chance of coyote losses. This also gives orphaned and weak young a greater chance to survive.

The average beef cattle calf production is about 78% nationwide. First-calf heifers need human assistance to give birth to a healthy calf about 40% of the time. Cow/calf producers who average 90% to 95% calf crops generally check their first-calf heifers every 2 hours during calving. Also, most good producers place first-calf heifers in small pastures (less than 160 acres [64 ha]). When all cows are bred to produce calves in a short, discreet (e.g. 60-day) period, production typically increases and predation losses decrease. The birth weight of calves born to first-calf heifers can be decreased by using calving-ease bulls, thus reducing birthing complications that often lead to coyote predation.

Producers who use lambing sheds or pens for raising sheep and small pastures or paddocks for raising cattle have lower predation losses than those who lamb or calve in large pastures or on open range. The more human presence around sheep, the lower the predation losses. Confining sheep entirely to buildings virtually eliminates predation losses.

Corrals. Although predation can occur at any time, coyotes tend to kill sheep at night. Confining sheep at night is one of the most effective means of reducing losses to predation. Nevertheless, some coyotes and many dogs are bold enough to enter corrals and kill sheep. A "coyote-proof" corral is a wise investment. Coyotes are more likely to attack sheep in unlighted corrals than in corrals with lights. Even if the corral fence is not coyote-proof, the mere fact that the sheep are confined reduces the risk of predation. Penning

sheep at night and turning them out at mid-morning might reduce losses. In addition, coyotes tend to be more active and kill more sheep on foggy or rainy days than on sunny days. Keeping the sheep penned on foggy or rainy days may be helpful.

Aside from the benefits of livestock confinement, there are some problems associated it. Costs of labor and materials associated with building corrals, herding livestock, and feeding livestock must be considered. In addition, the likelihood of increased parasite and disease problems may inhibit adoption of confinement as a method of reducing damage.

Carrion Removal. Removal and proper disposal of dead sheep and cattle are important since livestock carcasses tend to attract coyotes, habituating them to feed on livestock. Some producers reason that coyotes are less likely to kill livestock if there is carrion available. This may be a valid preventative measure if an adequate supply of carrion can be maintained far away from livestock. If a coyote becomes habituated to a diet of livestock remains, however, it may turn to killing livestock in the absence of carcasses. Wherever there is easily accessible carrion, coyotes seem to gather and predation losses are higher. Conversely, where carrion is generally not available, losses are lower. A study in Canada showed that the removal of livestock carcasses significantly reduced overwinter coyote populations and shifted coyote distributions out of livestock areas.

Habitat Changes. Habitat features change in some areas, depending on seasonal crop growth. Some cultivated fields are devoid of coyotes during winter but provide cover during the growing season, and a corresponding increase in predation on nearby livestock may occur.

The creation of nearly 40 million acres (16 million ha) of Conservation Reserve Program (CRP) acres may benefit many species of wildlife, including predators. These acres harbor prey for coyotes and foxes, and an increase in predator populations can reasonably be predicted. Clearing away weeds and brush from CRP areas may reduce predation problems since predators usually use cover in their approach to livestock. Generally, the more open the area where livestock are kept, the less likely that coyote losses will occur. Often junk piles are located near farmsteads. These serve as good habitat for rabbits and other prey and may bring coyotes into close proximity with livestock, increasing the likelihood for opportunistic coyotes to prey on available livestock. Removing junk piles may be a good management practice.

Pasture Selection. If sheep or beef cattle are not lambed or calved in sheds or lots, the choice of birthing pastures should be made with potential coyote predation problems in mind. Lambs and calves in remote or rugged pastures are usually more vulnerable to coyote predation than those in closer, more open, and smaller pastures. In general, a relatively small, open, tightly fenced pasture that can be kept under close surveillance is a good choice for birthing livestock that are likely targets of coyotes. Past experience with predators as well as weather and disease considerations should also serve as guides in the selection of birthing pastures.

A factor not completely understood is that, at times, coyotes and other predators will kill in one pasture and not in another. Therefore, changing pastures during times of loss may reduce predation. There may seem to be a relationship between size of pasture and predator losses, with higher loss rates reported in larger pastures. In reality, loss rates may not be related as much to pasture size as to other local conditions such as slope, terrain, and human populations. Hilly or rugged areas are typically sparsely populated by humans and are characterized by large pastures. These conditions are ideal for coyotes.

Sheep pastures that contain or are adjacent to streams, creeks, and rivers tend to have more coyote problems than pastures without such features. Water courses serve as hunting and travel lanes for coyotes.

Herders. Using herders with sheep or cattle in large pastures can help reduce predation, but there has been a trend away from herders in recent years because of increasing costs and a shortage of competent help. Nevertheless, tended flocks or herds receive closer attention than untended livestock, particularly in large pastures, and problems can be solved before they become serious. We recommend two herders per band of range sheep. If herders aren't used, daily or periodic checking of the livestock is a good husbandry practice.

Frightening Devices and Repellents

Frightening devices are useful for reducing losses during short periods or until predators are removed. The devices should not be used for long periods of time when predation is not a problem. To avoid acclimation you can increase both the degree and duration of effectiveness by varying the position, appearance, duration, or frequency of the frightening stimuli, or using them in various combinations. Many frightening methods have been ridiculed in one way or another; nevertheless, all of the techniques discussed here have helped producers by saving livestock and/or buying some time to institute other controls.

Lights. A study involving 100 Kansas sheep producers showed that using lights above corrals at night had the most marked effect on losses to coyotes of all the devices examined. Out of 79 sheep killed by coyotes in corrals, only three were killed in corrals with lights. Nearly 40% of the producers in the study used lights over corrals. There was some indication in the study that sheep losses to dogs were higher in lighted corrals, but the sample size for dog losses was small and the results inconclusive. Most of the producers (80%) used mercury vapor lights that automatically turned on at dusk and off at dawn.

Another advantage of lighted corrals is that coyotes are more vulnerable when they enter the lighted area. Coyotes often establish a fairly predictable pat-

tern of killing. When this happens in a lighted corral, it is possible for a producer to wait above or downwind of the corral and to shoot the coyote as it enters. Red or blue lights may make the ambush more successful since coyotes appear to be less frightened by them than by white lights.

Revolving or flashing the lights may enhance their effectiveness in frightening away predators. There is some speculation that the old oil lamps used in highway construction repelled coyotes, presumably because of their flickering effect.

Bells and Radios. Some sheep producers place bells on some or all of their sheep to discourage predators. Where effects have been measured, however, no difference in losses was detected.
Some producers use a radio tuned to an all-night station to temporarily deter coyotes, dogs, and other predators.

Vehicles. Parking cars or pickups in the area where losses are occurring often reduces predation temporarily. Effectiveness can be improved or extended by frequently moving the vehicle to a new location. Some producers place a replica of a person in the vehicle when losses are occurring in the daylight. If predators continue to kill with vehicles in place, the vehicle serves as a comfortable blind in which to wait and shoot offending predators.

Propane Exploders. Propane exploders produce loud explosions at timed intervals when a spark ignites a measured amount of propane gas. On most models, the time between explosions can vary from about 1 minute to 15 minutes. Their effectiveness at frightening coyotes is usually only temporary, but it can be increased by moving exploders to different locations and by varying the intervals between explosions. In general, the timer on the exploder should be set to fire every 8 to 10 minutes, and the location should be changed every 3 or 4 days. In cattle pastures, these devices should be placed on rigid stands above the livestock. Normally, the exploder should be turned on just before dark and off at daybreak, unless coyotes are killing livestock during daylight hours. Motion sensors are now available and likely improve their effectiveness, though it is still only temporary. Exploders are best used to reduce losses until more permanent control or preventive measures can be implemented. In about 24 coyote depredation complaints over a 2-year period in North Dakota, propane exploders were judged to be successful in stopping or reducing predation losses until offending coyotes could be removed. "Success time" of the exploders appears to depend a great deal on how well they are tended by the livestock producer.

Strobe Lights and Sirens. The USDA's Denver Wildlife Research Center developed a frightening device called the Electronic Guard (EG) (Fig. 6). The EG consists of a strobe light and siren controlled by a variable interval timer that is activated at night with a photoelectric cell. In tests conducted in fenced pastures, predation was reduced by about 89%. The device is used in Kansas and other states to protect cows/calves from coyote predation. Most research on the effectiveness of this device, however, has been done on sheep operations. Suggestions for using the unit differ for pastured sheep and range operations.

To use the EG in fenced pastures (farm flocks):

1. Place EGs above the ground on fence posts, trees, or T-posts so they can be heard and seen at greater distances and to prevent livestock from damaging them.
2. Position EGs so that rain water cannot enter them and cause a malfunction.
3. Locate EGs so that light can enter the photocell port or window. If positioned in deep shade, they may not turn on or off at the desired times.

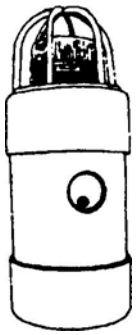

Fig. 6. Electronic Guard frightening device

4. The number of EGs used to protect sheep in fenced pastures depends on pasture size, terrain features, and the amount and height of vegetation in or around the pasture. In general, at least two units should be used in small (20 to 30 acres [8 to 12 ha]), level, short-grass pastures. Three to four units should be used in larger (40 to 100 acres [16 to 40 ha]), hilly, tall grass, or wooded pastures.
5. Don't use EGs in pastures larger than about 100 acres (40 ha) because their effective range is limited. The device could be useful in larger pastures when placed near areas where sheep congregate and bed at night.
6. EGs should be placed on high spots, where kills have been found, at the edge of wooded areas, near or on bedgrounds, or near suspected coyote travelways. They should be moved to different locations every 10 to 14 days to reduce the likelihood of coyotes getting used to them.

To use the EG in open range (herded or range sheep):

1. The number of EGs used will depend on the number of sheep in the band and the size of the bedground. Four units should be used to protect bands of 1,000 ewes and their lambs.
2. When possible, place one EG in the center of the bedground and the other three around the edge of the bedground. Try to place the units on coyote travelways.

3. EGs should be placed on high points, ridge tops, edges of clearings, or on high rocks or outcroppings. Hang the devices on tree limbs 5 to 7 feet (1.5 to 2.1 m) above ground level. If used above timberline or in treeless areas, hang them from a tripod of poles.
4. Herders who bed their sheep tightly will have better results than those who allow sheep to bed over large areas. Sheep that are bedded about 200 yards (166 m) or less in diameter, or are spread out not more than 200 to 400 yards (166 to 332 m) along a ridge top, can usually be protected with EGs.

Repellents. The notion of repelling coyotes from sheep or calves is appealing, and during the 1970s, university and government researchers tested a wide variety of potentially repellent chemical compounds on sheep. Both olfactory (smell) and gustatory (taste) repellents were examined. The underlying objective was to find a compound that, when applied to sheep, would prevent coyotes from killing them. Tests were conducted with various prey species including rabbits, chickens, and sheep. Some repellents were applied by dipping target animals in them, others were sprayed on, and some were applied in neck collars or ear tags.

Coyotes rely heavily on visual cues while stalking, chasing, and killing their prey. Taste and smell are of lesser importance in actually making the kill. These factors may in part account for the fact that the repellent compounds were not able to consistently prevent coyotes from killing, although some of the repellents were obviously offensive to coyotes and prevented them from consuming the killed prey. Several compounds were tested on sheep under field conditions, but none appeared to offer significant, prolonged protection.

If an effective chemical repellent were to be found, the obstacles in bringing it to industry use would be significant. The compound would not only need to be effective, but also persistent enough to withstand weathering while posing no undue risk to the sheep, other animals, or the environment. It would also have to withstand the rigorous Environmental Protection Agency (EPA) approval process.

Fig. 7. Livestock guarding dog (Akbash dog)

High-frequency sound has also been tested as a repellent for coyotes, but the results were no more encouraging than for chemical repellents. Coyotes, like dogs, responded to particular sound frequencies and showed some aversion to sounds broadcast within one foot (30 cm) of their ear. Researchers, however, were unable to broadcast the sound a sufficient distance to test the effects under field conditions. Aversive conditioning is well documented for averting rodents from food sources, but significant problems must be overcome before the method can be used to reduce coyote predation on sheep. Coyotes must be induced to eat sheep like baits that have been treated with the aversive chemical. The chemical must cause sufficient discomfort, such as vomiting, to cause coyotes to avoid other baits. Furthermore, the avoidance must be transferred to live sheep and must persist long enough without reinforcement for the method to offer realistic protection to sheep.

To date, pen and field tests with aversive conditioning have yielded conflicting and inconclusive results. It does not appear that aversive conditioning is effective in reducing predation, but additional field tests would be useful.

Guarding Animals.

Livestock Guarding Dogs. A livestock guarding dog is one that generally stays with sheep or cattle without harming them and aggressively repels predators. Its protective behaviors are largely instinctive, but proper rearing plays a part. Breeds most commonly used today include the Great Pyrenees, Komondor, Anatolian Shepherd, and Akbash Dog (Fig. 7). Other Old World breeds used to a lesser degree include Maremma, Sharplaninetz, and Kuvasz. Crossbreeds are also used.

The characteristics of each sheep operation will dictate the number of dogs required for effective protection from predators. If predators are scarce, one dog is sufficient for most fenced pasture operations. Range operations often use two dogs per band of sheep. The performance of individual dogs will differ based on age and experience. The size, topography, and habitat

of the pasture or range must also be considered. Relatively flat, open areas can be adequately covered by one dog. When brush, timber, ravines, and hills are in the pasture, several dogs may be required, particularly if the sheep are scattered. Sheep that flock and form a cohesive unit, especially at night, can be protected by one dog more effectively than sheep that are continually scattered and bedded in a number of locations.

The goal with a new puppy is to channel its natural instincts to produce a mature guardian dog with the desired characteristics. This is best accomplished by early and continued association with sheep to produce a bond between the dog and sheep. The optimum time to acquire a pup is between 7 and 8 weeks of age. The pup should be separated from litter mates and placed with sheep, preferably lambs, in a pen or corral from which it can't escape. This socialization period should continue with daily checks from the producer until the pup is about 16 weeks old. Daily checks don't necessarily include petting the pup. The primary bond should be between the dog and the sheep, not between the dog and humans. The owner, however, should be able to catch and handle the dog to administer health care or to manage the livestock. At about 4 months, the pup can be released into a larger pasture to mingle with the other sheep.

A guarding dog will likely include peripheral areas in its patrolling. Some have been known to chase vehicles and wildlife and threaten children and cyclists. These activities should be discouraged. Neighbors should be alerted to the possibility that the dog may roam onto their property and that some predator control devices such as traps, snares, and M-44s present a danger to it. Many counties enforce stringent laws regarding owner responsibility for damage done by roaming dogs. It is in the best interests of the owner, dog, and community to train the dog to stay in its designated area.

The use of guarding dogs does not eliminate the need for other predation control actions. They should, however, be compatible with the dog's behavior. Toxicants (including some insecticides and rodenticides) used to control various pest species can be extremely hazardous to dogs and are therefore not compatible with the use of guarding dogs.

If snares and traps are used where dogs are working, the producer should: (1) encourage the use of sets and devices that are likely not to injure the dog if it is caught, and (2) know where traps and snares are set so they can be checked if a dog is missing. Aerial hunting, as well as calling and shooting coyotes, should pose no threat to guarding dogs. Ensuring the safety of the dog is largely the producer's responsibility.

Dogs may be viewed as a first line of defense against predation in sheep and cow/calf operations in some cases. Their effectiveness can be enhanced by good livestock management and by eliminating predators with suitable removal techniques.

Donkeys. Although the research has not focused on donkeys as it has on guarding dogs, they are gaining in popularity as protectors of sheep and goat flocks in the United States. A recent survey showed that in Texas alone, over 2,400 of the 11,000 sheep and goat producers had used donkeys as guardians.

The terms *donkey* and *burro* are synonymous (the Spanish translation of *donkey* is *burro*) and are used interchangeably. Donkeys are generally docile to people, but they seem to have an inherent dislike of dogs and other canids, including coyotes and foxes. The typical response of a donkey to an intruding canid may include braying, bared teeth, a running attack, kicking, and biting. Most likely it is acting out of aggression toward the intruder rather than to protect the sheep. There is little information on a donkey's effectiveness with noncanid predators such as bears, mountain lions, bobcats, or birds of prey.

Reported success of donkeys in reducing predation is highly variable. Improper husbandry or rearing practices and unrealistic expectations probably account for many failures. Donkeys are significantly cheaper to obtain and care for than guarding dogs, and they are probably less prone to accidental death and premature mortality than dogs. They may provide a longer period of useful life than a guarding dog, and they can be used with relative safety in conjunction with snares, traps, M-44s, and toxic collars.

Researchers and livestock producers have identified several key points to consider when using a donkey for predation control:

1. Use only a jenny or a gelded jack. Intact jacks are too aggressive and may injure livestock. Some jennies and geldings may also injure livestock. Select donkeys from medium-sized stock.
2. Use only one donkey per group of sheep. The exception may be a jenny with a foal. When two or more adult donkeys are together or with a horse, they usually stay together, not necessarily near the sheep. Also avoid using donkeys in adjacent pastures since they may socialize across the fence and ignore the sheep.
3. Allow about 4 to 6 weeks for a naive donkey to bond to the sheep. Stronger bonding may occur when a donkey is raised from birth with sheep.
4. Avoid feeds or supplements containing monensin or lasolacid. They are poisonous to donkeys.
5. Remove the donkey during lambing, particularly if lambing in confinement, to avoid injuries to lambs or disruption of the lamb-ewe bond.

6. Test a new donkey's response to canids by challenging it with a dog in a pen or small pasture. Discard donkeys that don't show overt aggression to an intruding dog.
7. Use donkeys in smaller (less than 600 acres [240 ha]), relatively open pastures with not more than 200 to 300 head of livestock. Large pastures with rough terrain and vegetation and widely scattered livestock lessen the effectiveness of a donkey.

Llamas. Like donkeys, llamas have an inherent dislike of canids, and a growing number of livestock producers are successfully using llamas to protect their sheep. A recent study of 145 ranches where guard llamas were used to protect sheep revealed that average losses of sheep to predators decreased from 26 to 8 per year after llamas were employed. Eighty percent of the ranchers surveyed were "very satisfied" or "satisfied" with their llamas. Llamas reportedly bond with sheep within hours and offer advantages over guarding dogs similar to those described for donkeys.

Other Animals. USDA's Agricultural Research Service tested the bonding of sheep to cattle as a method of protecting sheep from coyote predation. There was clearly some protection afforded the sheep that remained near cattle. Whether this protection resulted from direct action by the cattle or by the coyotes' response to a novel stimulus is uncertain. Later studies with goats, sheep, and cattle confirmed that when either goats or sheep remained near cattle, they were protected from predation by coyotes. Conversely, goats or sheep that grazed apart from cattle, even those that were bonded, were readily preyed on by coyotes.

There are currently no research data available on the ideal ratio of cattle to sheep, the breeds of cattle, age of cattle most likely to be used successfully, or on the size of bonded groups to obtain maximum protection from predation. Multispecies grazing offers many advantages for optimum utilization of forage, and though additional study and experience is needed, it may also be a tool for coyote damage control.

Any animal that displays aggressive behavior toward intruding coyotes may offer some benefit in deterring predation. Other types of animals reportedly used for predation control include goats, mules, and ostriches. Coyotes in particular are suspicious of novel stimuli. This behavior is most likely the primary reason that many frightening tactics show at least temporary effectiveness.

Trapping

Body-gripping traps are illegal for use in commercial fur or recreational application in California (see regulations

There are zones throughout California where the use of Conibear-type traps and snares, except those totally submerged, and deadfall traps are prohibited for the protection of the San Joaquin kit fox and Sierra Nevada red fox (see regulations).

There are many effective methods for trapping coyotes, and success can be enhanced by considering several key points. Coyotes learn from past events that were unpleasant or frightening, and they often avoid such events in the future. In spring and summer, most coyotes limit their movements to a small area, but in late summer, fall, and winter they may roam over a larger area. Coyotes follow regular paths and crossways, and they prefer high hills or knolls from which they can view the terrain. They establish regular scent posts along their paths, and they depend on their ears, nose, and ears to sense danger.

Snares

Snaring is the technique of setting a steel-cable loop in an animal's path to capture it by the neck, body, or leg. Snares usually consist of a 2.5- to 10-foot (0.75- to 3.0-m) long piece of galvanized aircraft cable containing a slide lock that forms a loop in the cable (Fig. 31). On short snares, a swivel to prevent twisting and breaking the cable is attached to the end of the cable opposite the loop. On longer snares, swivels can be located near the middle of the cable and at one end.

Snares offer several advantages over steel foothold traps. They are lightweight, compact, simple in function, affected little by weather, easy to set, low in cost, and offer a high degree of human safety. In a south Texas study, snares were 10 times more selective over steel foothold traps for target species of coyotes and bobcats. Snares, however, can be a greater hazard than traps to livestock. Recent research has produced deer stops and break-away or relaxing locks that have significantly improved snare specificity.

Preparation of Snares. New commercial snares and extension cables can be cleaned by boiling each dozen snares in a pan or bucket of water with 4 tablespoons (16 gm) of baking soda for one hour. The snares will turn a dull gray after being removed from this bath and hung up to dry outdoors. Darken snares by boiling them in brown logwood crystals and dye. After boiling, snares should be kept clean of foreign odors. Wear clean gloves when handling and setting snares.

How to Set Snares. Snares designed to capture predators by the neck or leg are set directly in the animal's path of movement and are held in place using various techniques. One support that works particularly well can be constructed from a 36-inch (0.9-m) piece of 12-gauge galvanized or 9-gauge soft

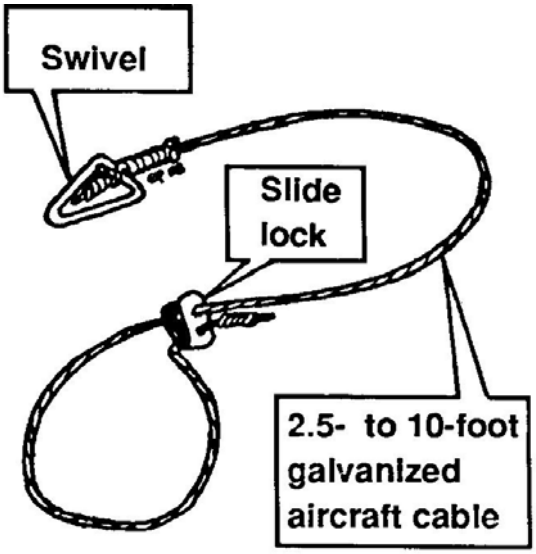

Fig. 31. Coyote snare

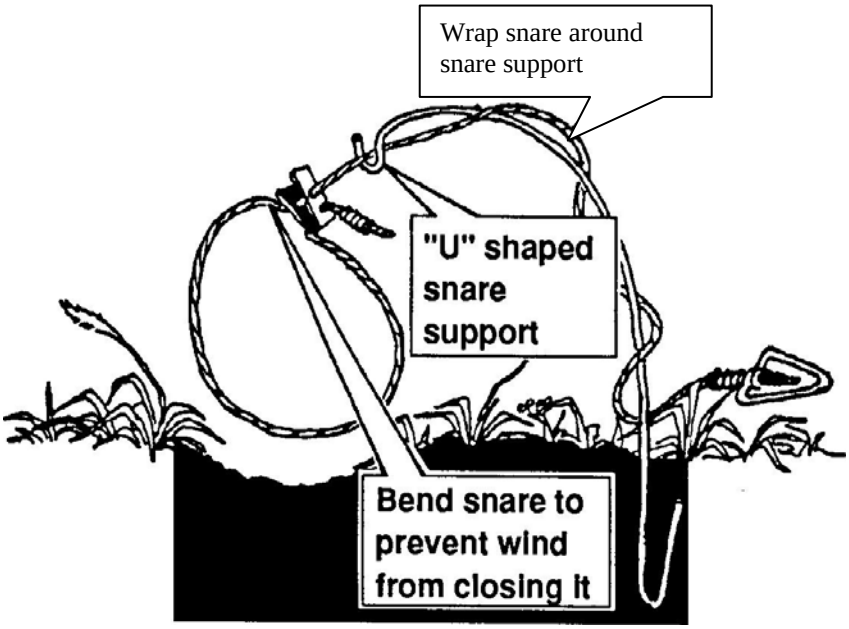

Fig. 33. Setting the snare

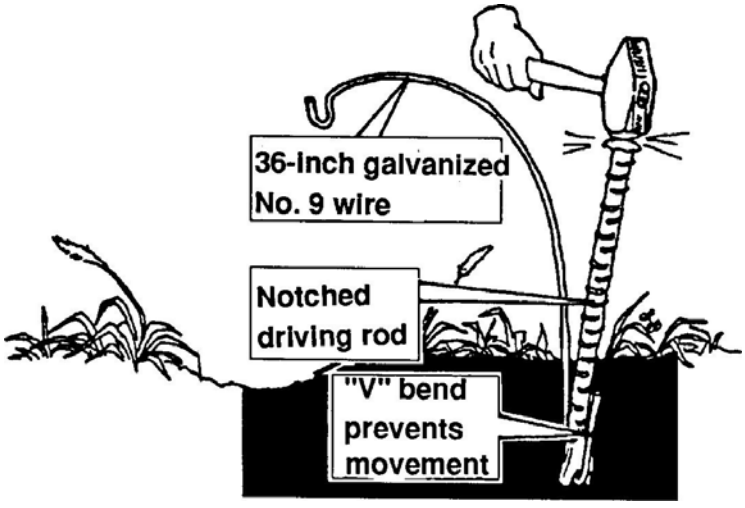

Fig. 32. Driving the support wire

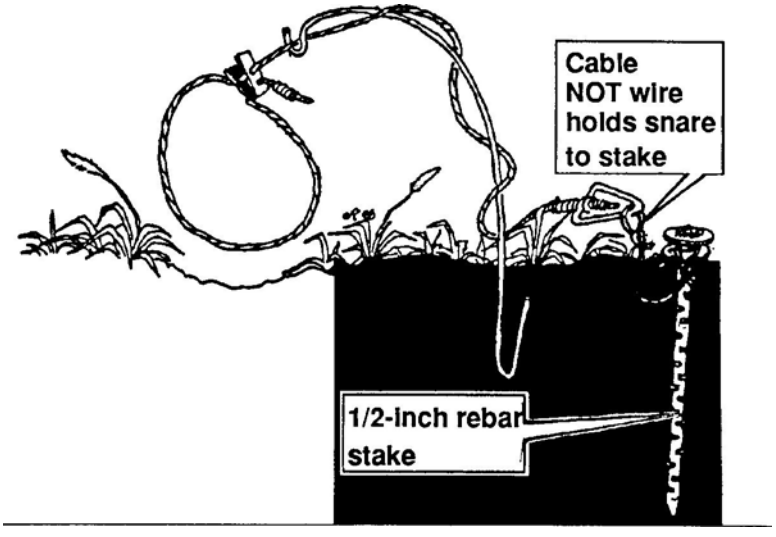

Fig. 34. Fastening the snare to the stake

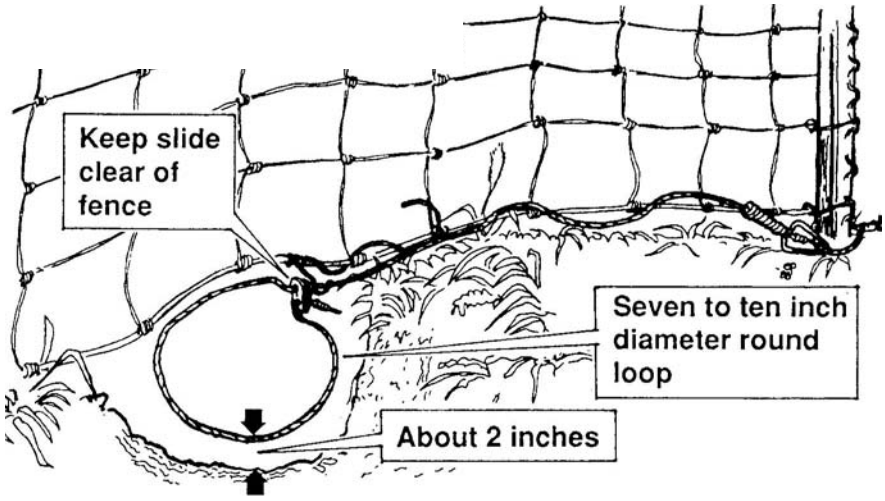

Fig. 35. Snare set for woven wire

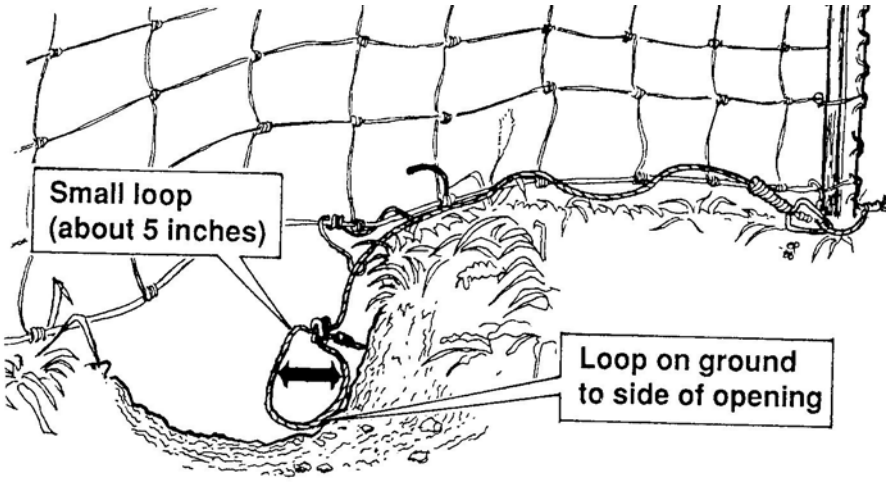

Fig. 36. Leg snare set

wire. Form a V bend in the support wire, about 4 inches (10 cm) from the end, and drive the wire into the ground with a notched rod (Fig. 32) to prevent the support from moving in the wind. Wrap the snare around the support about three times and hold it in place with a U bend formed in the upper end of the snare support. Bend the snare cable upward slightly, just inside the lock, to ensure that the snare loop is not closed by the wind (Fig. 33).

Snares should be attached to a solid object so that captured animals cannot escape (Fig. 34). A steel 1/2-inch (1.3-cm) diameter rebar, 24 to 30 inches (61 to 72 cm) long (depending on soil hardness), makes a good anchor for coyotes and smaller predators. Attach snares to the rebar with a strong swivel to prevent tangling and breaking. A lead cable that is at least as strong as the snare cable can be used to attach short snares to the rebar stake. Avoid using 9-gauge (0.38-cm) wire or several strands of 14-gauge (0.21-cm) wire to anchor snares to a rebar stake because they may bend back and forth, crystallize, and break.

When used for coyotes, snares also can be secured to a dead tree limb that is at least 6 inches (15 cm) in diameter and 6 feet (2 m) long.

Snares set in holes under woven-wire fences can be held in place about 1 to 2 inches (2.5 to 5 cm) from the fence with the snare support system (Fig. 35). The snare should be set far enough away from the fence to prevent the lock from catching on the bottom wire of the fence. The bottom of the loop should be about 2 inches (5 cm) above the bottom of the hole. The snares can be anchored to the heavy-gauge wire on the bottom of the fence. Two strands of baling wire or S hooks can be used to fasten the snare to the bottom wire.

If there is a chance of accidentally catching a pet dog, a leg snare set is recommended (Fig. 36). Set a small loop about 5 inches (13 cm) or less to one side of the opening, and set the bottom of the loop on the ground. When a coyote goes under a fence, it places both front feet firmly on the ground, and sticks its head just under the bottom wire. Once its head is past the bottom wire, the coyote begins to raise its head. The idea is to set the leg snare so that one front foot will pass through the snare.

Snares are usually set in the form of a round or oval loop. In a trail set (Fig. 37), a round loop that is 12 inches (30 cm) in diameter can form an oval loop that is about 14 inches (36 cm) high and 10 inches (25 cm) wide. Use a 5/64- or 3/32-inch (0.2- or 0.24-cm) diameter galvanized aircraft cable for snaring coyotes. Varying round loop diameters and heights above ground is recommended when snaring coyotes (Table 1). The loop size in a hole in a fence should vary depending upon the size of the hole.

Table 1.Specific loop dimensions for snaring coyotes.

Type of set	Round loop Diameter in inches	(cm)	Height of loop above ground in inches	(cm)
Trail	9-12	(23-30)	10-12	(25-30)
Under fence	7-10	(18-25)	2	(5)

Where to Set Snares. Animals usually follow the easiest route through heavy cover. These routes, which generally consist of trails, are excellent locations to snare predators. Snares are effective along trails leading to draw stations. Some effective locations for snaring coyotes include: (1) along trails in thickets or heavy vegetation leading to a carcass, (2) on trails under fences, (3) on livestock trails in vacant pastures, (4) in the bottoms of ravines, and 5) on narrow paths inside weeds or brush. Trails can be created by driving on weeds or stubble with a pickup, by walking in snow, or by mowing a trail through weeds or grass with a weed eater.

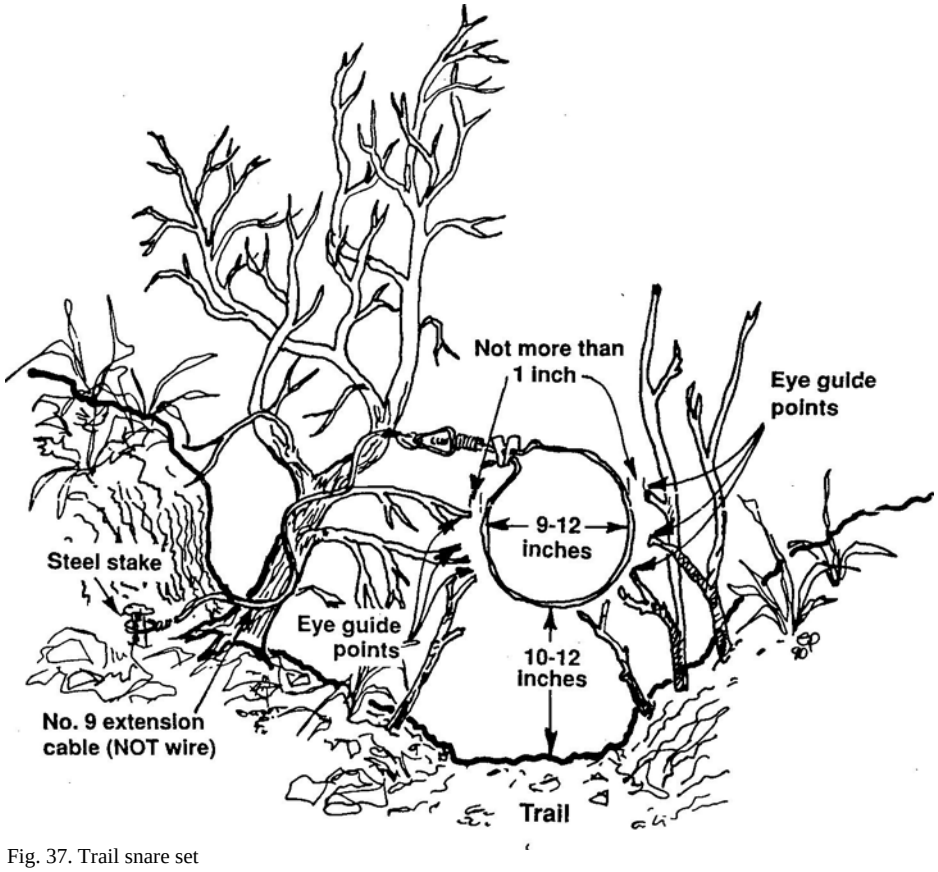

Fig. 37. Trail snare set

Regulations for Snaring. See California laws and regulations regarding the use of snares. Snares should be checked early in the morning to increase the probability of releasing nontarget animals unharmed.

Methods to Avoid Capturing Nontarget Animals. Sites where snares are set should be carefully selected to avoid capturing nontarget animals. Avoid setting snares: (1) in pastures with livestock, (2) within 25 yards (23 m) of animal carcasses (to prevent capturing birds of prey and other scavengers), (3) within major deer, elk, or antelope wintering areas (these big game animals are much less susceptible to foothold traps), (4) on any trails being used by livestock, deer, elk, and other nontarget animals (attract predators away from these trails with specific baits and lures), (5) under fences where livestock, antelope, deer, or nontarget dogs are using the "crawl space," and (6) where people can readily view captured animals.

Use a short snare cable to reduce injuries where accidentally captured dogs might jump over a fence or a tree branch. Also avoid using entangling devices (attachments that increase the chance of killing the snared animal) where dogs might be captured. Use the lightest snare lock (breakaway lock) possible to capture the desired animal. If livestock, deer, elk, or antelope are captured by a leg, they can usually break a light lock but may be held by heavy locks. Record the location and number of snares on a map so they can be found, and remove all snares when damage stops or when they cannot be checked frequently.

Shooting

Shooting coyotes is legal in many situations, and it often ranks high among the choices for removing a predator. Safety, however, is a critical factor that in some circumstances may preclude the use of firearms (for example, local laws may prohibit shooting, or neighbors may be too close).

For shooting coyotes, a medium-powered bolt-action rifle fitted with a scope is recommended. The .223 Remington, .22-250, .220 Swift, or the .243 Winchester are all capable of killing a coyote up to a distance of 250 yards (225 m). Since coyotes are able to detect human scent, the shooter should take a stand downwind from where the coyote will likely approach. An elevated location where the lighting works to the shooter's advantage is a good choice. If predators are killing sheep in the daytime, construct a comfortable blind at a vantage point in the pasture where the killing has occurred. Whenever possible, rest the rifle on a solid support while aiming. A homemade shooting stick will improve accuracy over shooting freehand.

A shotgun, preferably a 12-gauge semi-automatic, can be used for shooting at short range (less than 50 yards [45 m]). Often it is advisable to have both a 12-gauge shotgun and a scoped rifle available. Copper-coated (BB) lead shot, No. 4 buckshot (lead), and in newer shotguns, the larger-sized steel shot works well for killing coyotes.

Calling and Shooting Coyotes. Coyotes may respond to predator calls. Calling, like other methods of predation control, should be used sparingly and only when needed. Coyotes can be called at any time of the day although the first couple of hours after dawn and the last few hours before darkness are usually best. Call in areas where there are signs of coyotes, such as tracks or droppings.

In some situations, coyotes can be located by listening to their howling at sundown and sunrise. Some hunters use sirens to elicit howls from coyotes. Often a voice imitation of a coyote howl works as well. Coyotes often come to a howl without howling back, so the prudent hunter is always ready to shoot.

Hunting at Night. See California Code of Regulations, Title 14, Sections 264 and 264.5. Not many people have witnessed predators killing live stock because it usually occurs at night, away from human activity. As stated previously, calling and shooting predators at night is illegal in many states. Where legal, however, hunting at night with the use of artificial lights may be effective. Red or blue light tends to spook predators less readily than white light does. Calling without the use of artificial lights is effective only with snow cover and the light of a full moon.

Hunting with Dogs. Several breeds are generally known as trailing hounds, including Walkers, Julys, redbones, blueticks, black and tans, Plott hounds, and English fox hounds. Trail hounds follow the scent left by a predator and run it to tree or bay it on the ground. Coyotes are seldom caught and killed by trail hounds. In most instances, trail hounds are used in combination with sight hounds. The trail hounds run coyotes into the open, and then sight hounds are released to capture the fleeing coyote. More commonly, coyotes are shot as they run from the pack of hounds. Sight hounds, generally greyhounds or Russian wolf hounds, are used in open prairie country to run coyotes down and kill them.

Economics of Damage and Control

Sheep numbers in the United States have declined about 80% from 1942 to 1976 (Gee et al. 1977). Former sheep producers reported that the principal reasons for leaving the sheep industry included high predation losses, low lamb and wool prices, a shortage of good hired labor, and the producer's age.

The US Fish and Wildlife Service (1978) estimated the economic impact of coyote predation on producers with predator problems, on producers without predator problems, and on consumers during 1977. They used an average lamb loss rate of 4% (267,000 lambs) and a ewe loss rate of 1.5% (125,000 ewes) to estimate an economic loss of $19 million to producers from coyote predation in the 17 western states. The reduced number of sheep and lambs resulted in a higher market price, which benefited producers by $6 million. The net impact of coyote predation on sheep producers was a loss of $13 million, and the impact on consumers was $4 million in additional costs. The General Accounting Office (GAO 1990) estimated that coyotes in 17 western states killed sheep and lambs valued at $18 million in 1989. The National Agricultural Statistical Service (NASS 1991) reported that sheep and lamb losses to coyotes in the United States were valued at $18.3 million in 1990.

The US Fish and Wildlife Service (1978) reported calf losses between birth and weaning to coyotes across the United States at 0.4%, with predation decreasing to nearly zero by weaning time. Dorrance (1982) reported that coyotes were responsible for 16% of the 1,520 confirmed predation losses of cattle in Alberta from 1974 to 1978. Coyote predation on calves caused producers with coyote problems across the United States to lose an estimated $20 million. However, because of the greater price flexibility of beef compared with sheep, the reduction in the number of beef calves marketed (estimated at 0.4%, or 115,000 fewer calves) resulted in a higher price, which benefited beef producers by $81 million. The net impact of the reduced supply of beef as a result of coyote predation was a gain of $61 million to beef producers, but it cost consumers an additional $98 million in higher prices for beef, resulting in an overall loss of $37 million. NASS (1992) reported that cattle and calf losses to coyotes in the United States were valued at $24.3 million in 1991.

Coyote predation also can cause substantial losses of domestic goats. In three studies in Texas, where an estimated 1.1 million goats (about 90% of the goats in the United States) are raised (Scrivner et al. 1985), predators were reported to take 18.1% of the adults and 33.9% of the kids (Pearson 1986). NASS (1991) reported that goat losses to coyotes in the United States were valued at $5.7 million in 1990.

Pearson (1986) stated that predators, particularly coyotes, accounted for losses of hundreds of chickens and turkeys in the 14 western states. In one study, Andelt and Gipson (1979) reported that between June 4 and August 31, 1976, a mated pair of coyotes apparently killed 268 domestic turkeys in Nebraska valued at $938.

Although the average value of livestock losses to coyotes reflected the overall impact on producers, it did not reflect the severity of losses to some individuals. Balser (1964) and Gee et al. (1977) indicated that coyote predation is much more serious for some producers than others. Most sheep producers suffer no or minor predator losses, whereas 20% to 25% of the producers suffer losses that are significantly higher than the average (US Fish Wildl. Serv. 1978). These losses can drive producers out of business because of low profit margins. Nonfatal injuries and harassment of livestock by coyotes also can result in reduced weight gain and subsequent reductions in profit.

Acknowledgments

Much of the information and several of the figures for this chapter were adapted from the *SID Sheep Production Handbook,* Predator Damage Control chapter, published by the American Sheep Industry Association, Inc. (1990) and various publications authored by F. R. Henderson, J. S. Green, W. F. Andelt, G. E. Connolly, and D. A. Wade.

The section on economics of damage and control was adapted from Andelt (1987).

Figure 1 by Emily Oseas Routman.

Figure 6 adapted from a USDA-APHIS-ADC illustration by Renee Lanik, University of Nebraska-Lincoln.

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Editors

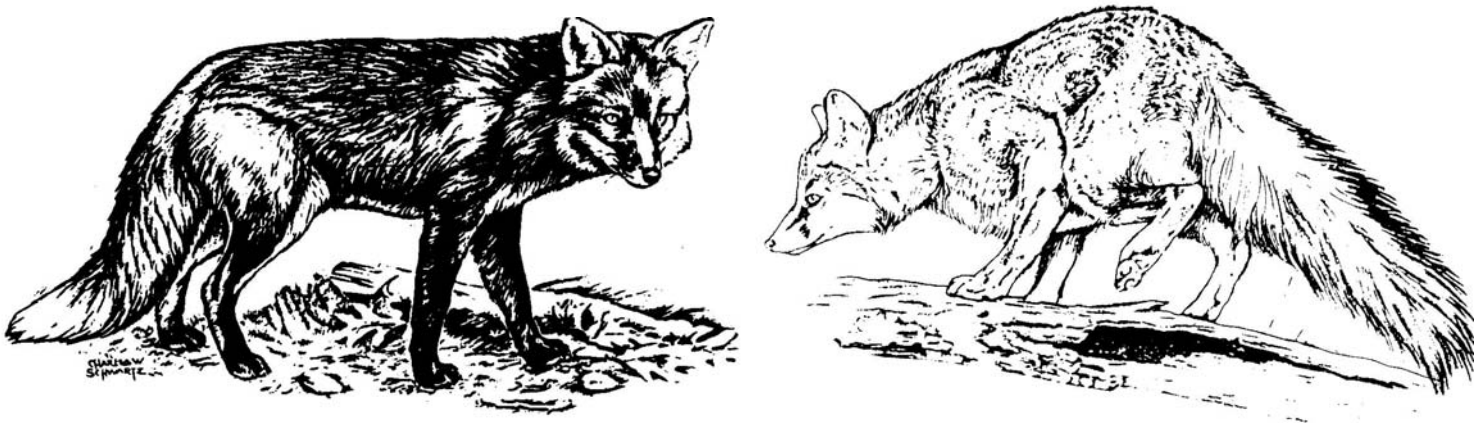
Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Robert L. Phillips
Wildlife Research Biologist
Denver Wildlife Research Center
USDA-APHIS-ADC
Denver, Colorado 80225-0266

Robert H. Schmidt
Assistant Professor
Department of Fisheries and Wildlife
Utah State University
Logan, Utah 84322-5210

FOXES

Fig. 1. Red fox, *Vulpes vulpes* (left) and gray fox, *Urocyon cinereoargenteus* (right).



Damage Prevention and Control Methods

Exclusion

Net wire fence.

Electric fence.

Cultural Methods

Protect livestock and poultry during most vulnerable periods (for example, shed lambing, farrowing pigs in protective enclosures).

Frightening

Flashing lights and exploders may provide temporary protection.

Well-trained livestock guarding dogs may be effective in some situations.

Repellents

None are registered for livestock protection.

Trapping

Body-gripping traps are illegal for use in commercial fur or recreational application in California (see regulations).

There are zones throughout California where the use of Conibear-type traps and snares, except those totally submerged, and deadfall traps are prohibited for the protection of the San Joaquin kit fox and Sierra Nevada red fox (see regulations).

Shooting

Predator calling techniques.

PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994
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Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln
United States Department of Agriculture
Animal and Plant Health Inspection Service
Animal Damage Control
Great Plains Agricultural Council
Wildlife Committee

Identification

California has four species of foxes: Both native and introduced populations of the red fox (*Vulpes vulpes*); the gray fox (*Urocyon cinereoargenteus*); the island gray fox (*Urocyon litoralis*); and the kit fox (*V. macrotis).* The red fox is the most common of the foxes native to North America. Most depredation problems are associated with red foxes, although in some areas gray foxes can cause problems. Few damage complaints have been associated with the kit fox.

The red fox is dog-like in appearance, with an elongated pointed muzzle and large pointed ears that are usually erect and forward. It has moderately long legs and long, thick, soft body fur with a heavily furred, bushy tail (Fig. 1). Typically, red foxes are colored with a light orange-red coat, black legs, lighter-colored underfur and a white- tipped tail. Silver and cross foxes are color phases of the red fox. In North America the red fox weighs about 7.7 to 15.4 pounds (3.5 to 7.0 kg), wit h males on average 2.2 pounds (1 kg) heavier than females.

Gray foxes weigh 7 to 13 pounds (3.2 to 5.9 kg) and measure 32 to 45 inches (81 to 114 cm) from the nose to the tip of the tail (Fig. 1). The color pattern is generally salt-and-pepper gray with buffy underfur. The sides of the neck, back of the ears, legs, and feet are rusty yellow. The tail is long and bushy with a black tip.

The island gray fox has pepper-and-salt upper pelage with a rufous or buffy underfur and a dorsal median black stripe ending in the black tip of the tail.

Kit foxes are not usually associated with livestock and poultry depredation because they typically eat small rodents and lead a secretive life in remote habitats away from people, although they may cause site-specific damage problems.

Please refer to appendices B, C, and D for additional information on gray, kit, and red foxes in California.

Range

Red foxes occur over most of North America, north and east from southern California, Arizona, and central Texas. They are found throughout most of the United States with the exception of a few isolated areas (Fig. 2).

The only native red fox in California is the Sierra Nevada red fox (*V. v. necator*). Because of the Sierra Nevada red fox's high mountain range, it is rarely associated with property damage. The introduced nonnative eastern red fox (V. v. regalis) is the more common red fox seen in lowland California. Eastern red foxes were introduced to California during the early 1900's by the fur farming industry. The red foxes that exist in the lower elevations of California are descendants of red foxes that either escaped from, or were released by the fur farming trade. Eastern red foxes are very competitive for habitat and because of their adaptive nature, are rapidly increasing throughout much of California. The hastening decline of some endangered species is related to the increased presence of and predation by the eastern red fox.

Gray foxes are found throughout the eastern, north central, and southwestern United States They are found throughout Mexico and most of the southwestern United States from California northward through western Oregon (Fig. 3).

The island gray fox is restricted to 6 of the Channel Islands off the coast of southern California. The island gray fox are common on Santa Cruz, Santa Rosa, and San Clemente islands, less common on San Nicolas and San Miguel, and rare on Santa Catalina.

Kit foxes are residents of arid habitats. They are found from extreme southern Oregon and Idaho south along the Baja Peninsula and eastward through southwestern Texas and northern Mexico (Fig. 4).

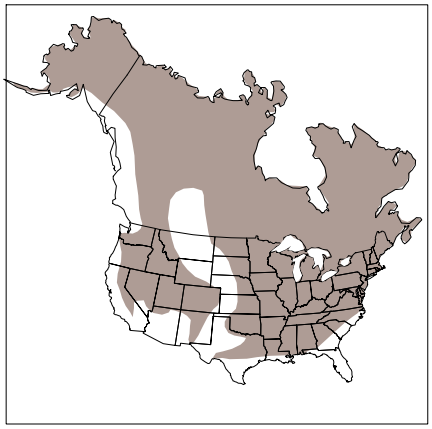

Fig. 2. Range of the red fox in North America.

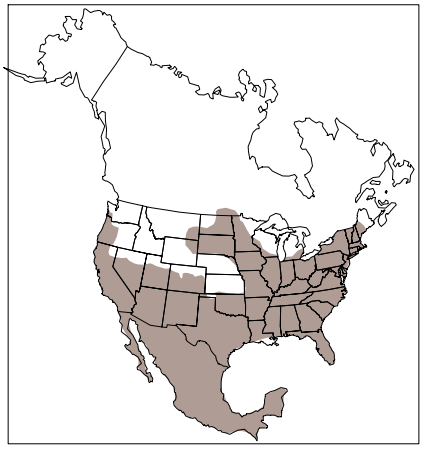

Fig. 3. Range of the gray fox in North America

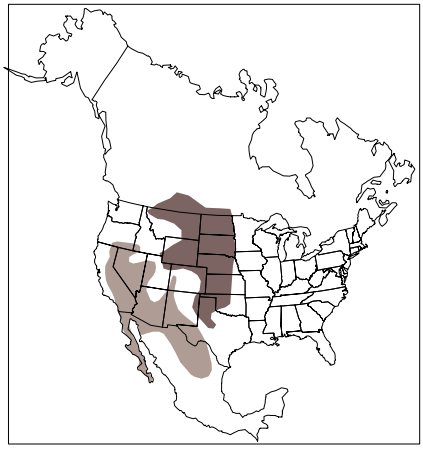

Fig. 4. Range of the swift fox (dark) and the kit fox (light) in North America.

Habitat

The red fox is adaptable to most habitats within its range, but usually prefers open country with moderate cover. Some of the highest fox densities reported are in the north-central United States, where woodlands are interspersed with farmlands. The range of the red fox has expanded in recent years to fill habitats formerly occupied by coyotes (*Canis latrans*). The reduction of coyote numbers in many sagebrush/grassland areas of Montana and Wyoming has resulted in increased fox numbers. Red foxes have also demonstrated their adaptability by establishing breeding populations in many urban areas of the United States, Canada, and Europe. Gray foxes prefer more dense cover such as thickets, riparian areas, swamp land, or rocky pinyon-cedar ridges. In eastern North America, this species is closely associated with edges of deciduous forests. Gray foxes can also be found in urban areas where suitable habitat exists. Optimum habitats for island gray foxes are mixed chaparral, coastal scrub, and shrubby stages of valley foothill

Food Habits

Foxes are opportunists, feeding mostly on rabbits, mice, bird eggs, insects, and native fruits. Foxes usually kill animals smaller than a rabbit, although fawns, pigs, kids, lambs, and poultry are sometimes taken. The fox's keen hearing, vision and sense of smell aid in detecting prey. Foxes stalk even the smallest mice with skill and patience. The stalk usually ends with a sudden pounce onto the prey. Red foxes sometimes kill more than they can eat and bury food in cashes for later use. All foxes feed on carrion (animal carcasses) at times.

General Biology, Reproduction, and Behavior

Foxes are crepuscular animals, being most active during the early hours of darkness and very early morning hours. They do move about during the day, however, especially when it is dark and overcast. Foxes are solitary animals except from the winter breeding season through midsummer, when mates and their young associate closely. Foxes have a wide variety of calls. They may bark, scream, howl, yap, growl, or make sounds similar to a hiccup. During winter a male will often give a yelling bark, "wo-wo-wo," that seems to be important in warning other male foxes not to intrude on its territory. Red foxes may dig their own dens or use abandoned burrows of a woodchuck or badger. The same dens may be used for several generations. Gray foxes commonly use wood piles, rocky out-crops, hollow trees, or brush piles as den sites. Foxes use their urine and feces to mark their territories.

Mating in red foxes normally occurs from mid-January to early February. At higher latitudes (in the Arctic) mating occurs from late February to early March. Estrus in the vixen lasts 1 to 6 days, followed by a 51- to 53-day gestation period. Fox pups can be born from March in southern areas to May in the arctic zones. Red foxes generally produce 4 to 9 pups. Gray foxes usually have 3 to 7 pups per litter. Arctic foxes may have from 1 to 14 pups, but usually have 5 or 6. Foxes disperse from denning areas during the fall months and establish breeding areas in vacant territories, sometimes dispersing considerable distances.

Damage and Damage Identification

Foxes may cause serious problems for poultry producers. Turkeys raised in large range pens are subject to damage by foxes. Losses may be heavy in small farm flocks of chickens, ducks, and geese. Young pigs, lambs, and small pets are also killed by foxes. Damage can be difficult to detect because the prey is usually carried from the kill site to a den site, or uneaten parts are buried. Foxes usually attack the throat of young livestock, but some kill by inflicting multiple bites to the neck and back. Foxes do not have the size or strength to hold adult livestock or to crush the skull and large bones of their prey. They generally prefer the viscera and often begin feeding through an entry behind the ribs. Foxes will also scavenge carcasses, making the actual cause of death difficult to determine. Pheasants, waterfowl, other game birds, and small game mammals are also preyed upon by foxes. At times, fox predation may be a significant mortality factor for upland and wetland birds, including some endangered species.

Rabies outbreaks are most prevalent among red foxes in southeastern Canada and occasionally in the eastern United States. The incidence of rabies in foxes has declined substantially since the mid-1960s for unexplained reasons. In 1990, there were only 197 reported cases of fox rabies in the United States as compared to 1,821 for raccoons and 1,579 for skunks. Rabid foxes are a threat to humans, domestic animals, and wildlife.

Legal Status

In California, gray fox, kit fox, and red fox are designated fur-bearing mammals. The Sierra Nevada red fox is State-listed Threatened and the San Joaquin kit fox (*V. m.mutica*) is also State-listed Threatened and Federally-listed Endangered (Appendix A).

It is illegal to trap Sierra Nevada red foxes and kit foxes, and no red fox may be taken for profit making purposes. See California statutes and regulations regarding the take of furbearing and nongame mammals.

Damage Prevention and Control Methods

Exclusion

Construct net wire fences with openings of 3 inches (8 cm) or less to exclude red foxes. Bury the bottom of the fence 1 to 2 feet (0.3 m to 0.9 m) with an apron of net wire extending at least 12 inches (30 cm) outward from the bottom. A top or roof of net wire may also be necessary to exclude all foxes, since some will readily climb a fence.

A 3-wire electric fence with wires spaced 6 inches, 12 inches, and 18 inches (15 cm, 31 cm, and 46 cm) above the ground can repel red foxes. Combination fences that incorporate net and electric wires are also effective.

Cultural Methods

The protection of livestock and poultry from fox depredation is most important during the spring denning period when adults are actively acquiring prey for their young. Watch for signs of depredation during the spring, especially if there is a history of fox depredation. Foxes, like other wild canids, will often return to established denning areas year after year. Foxes frequently den in close proximity to human habitation. Dens may be located close to farm buildings, under haystacks or patches of cover, or even inside hog lots or small pastures used for lambing. Because of the elusive habits of foxes, dens in these locations may not be noticed until excessive depredations have occurred.

The practice of shed lambing and farrowing in protected enclosures can be useful in preventing fox depredation on young livestock. Also, removal of Livestock carcasses from production areas can make these areas less attractive to predators.

Frightening

Foxes readily adapt to noise-making devices such as propane exploders, timed tape recordings, amplifiers, or radios, but such devices may temporarily reduce activity in an area. Flashing lights, such as a rotating beacon or strobe light, may also provide temporary protection in relatively small areas or in livestock or poultry enclosures. Combinations of frightening devices used at irregular intervals should provide better protection than use of a single device because animals may have more difficulty in adapting to these disturbances. When properly trained, some breeds of dog, such as Great Pyrenees and Akbash dogs, have been useful in preventing predation on sheep. The effectiveness of dogs, even the "guard dog" breeds, seems to depend entirely on training and the individual disposition of the dog.

Trapping

Body-gripping traps are illegal for use in commercial fur or recreational application in California (see regulations).
There are zones throughout California where the use of Conibear-type traps and snares, except those totally submerged, and deadfall traps are prohibited for the protection of the San Joaquin kit fox and Sierra Nevada red Fox (see regulations).

Trapping is a very effective and selective control method. A great deal of expertise is required to effectively trap foxes. Trapping by inexperienced people may serve to educate foxes, making them very difficult to catch, even by experienced trappers.

Proper set location is important when trapping foxes. Sets made along trails, at entrances to fields, and near carcasses are often most productive.

Cage traps are sometimes effective for capturing juvenile red foxes living in urban areas. It is uncommon to trap an adult red fox in a cage or a box trap.

Snares made from 1/16-inch, 5/64-inch, and 3/32-inch (0.15 cm, 0.2 cm, and 0.25 cm) cable can be very effective for capturing both red and gray foxes. Snares are generally set in trails or in crawl holes (under fences) that are frequented by foxes. The standard

loop size for foxes is about 6 inches (15 cm) with the bottom of the loop about 10 to 12 inches (25 to 30 cm) above ground level (Fig. 7). Trails leading to and from den sites and to carcasses being fed on by foxes make excellent locations for snares.

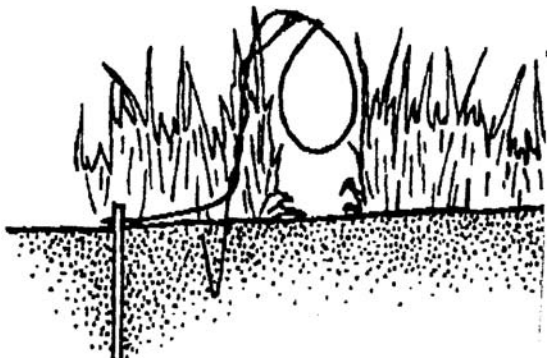

Fig. 7. Properly set neck snare for foxes.

Shooting

Harvest of foxes by sport hunters and fur trappers is another method of reducing fox populations in areas where damage is occurring. Livestock and poultry producers who have predation problems during the late fall and winter can sometimes find private fur trappers willing to hunt or trap foxes around loss sites. Depredations are usually most severe, however, during the spring when furs are not saleable, and it is difficult to interest private trappers at that time.

Artificial rabbit distress calls can be used to decoy foxes to within rifle or shotgun range. Select a spot that faces into the wind, at the edge of a clearing or under a bush on a slight rise where visibility is good. Blow the call at 1/2- to 1-minute intervals, with each call lasting 5 to 10 seconds. If a fox appears, remain motionless and do not move the rifle or shotgun until ready to shoot. If a fox does not appear in about 20 minutes, move to a new spot and call again.

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Figure 1 from Schwartz and Schwartz (1981) adapted by Jill Sack Johnson.

Figures 2, 3, and 4 courtesy of Pam Tinnin. Figure 7 courtesy of Tom Krause.

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Editors

Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Edward K. Boggess
Wildlife Program Manager
Minnesota Department of
Natural Resources
St. Paul, Minnesota 55155

MINK

Fig. 1. The mink, *Mustela vison,* is a semiaquatic furbearer well known for its high-quality fur.

Damage Prevention and Control Methods

Exclusion

Exclusion usually is the best solution to mink predation on domestic animals. Confine animals in fenced areas. Seal all openings larger than 1 inch (2.5 cm).

Habitat Modification

Generally not feasible.

Frightening

No methods are effective.

Trapping

Body-gripping traps are illegal for use in commercial fur or recreational application in California (see regulations).

There are zones throughout California where the use of Conibear-type traps and snares, except those totally submerged, and deadfall traps are prohibited for the protection of the San Joaquin kit fox and Sierra Nevada red fox (see regulations).

Shooting

Normally difficult and impractical.

Identification

The mink (*Mustela vison*, Fig. 1) is a member of the weasel family. It is about 18 to 24 inches (46 to 61 cm) in length, including the somewhat bushy 5- to 7-inch (13- to 18-cm) tail, and weighs 1 1/2 to 3 pounds (0.7 to 1.4 kg). Females are about three-fourths the size of males. Both sexes are a rich chocolate-brown color, usually with a white patch on the chest or chin and scattered white patches on the belly. The fur is relatively short with the coat consisting of a soft, dense underfur concealed by glossy, lustrous guard hairs. Mink also have anal musk glands common to the weasel family and can discharge a disagreeable musk if frightened or disturbed. Unlike skunks, however, they cannot forcibly spray musk.

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Range and Habitat

Mink are found throughout North America,with the exception of the desert southwest and tundra areas (Fig. 2).

Mink are shoreline dwellers and their one basic habitat requirement is a suitable permanent water area. This may be a stream, river, pond, marsh, swamp, or lake. Waters with good populations of fish, frogs, and aquatic invertebrates and with brushy or grassy ungrazed shorelines provide the best mink habitat. Mink use many den sites in the course of their travels and the availability of adequate den sites is a very important habitat consideration. These may be muskrat houses, bank burrows, holes, crevices, log jams, or abandoned beaver lodges.

Food Habits

The mink is strictly carnivorous. Because of its semiaquatic habits, it obtains about as much food on land as in water. Mink are opportunistic feeders with a diet that includes mice and rats, frogs, fish, rabbits, crayfish, muskrats, insects, birds, and eggs.

General Biology, Reproduction, and Behavior

Mink are polygamous and males may fight ferociously for mates during the breeding season, which occurs from late January to late March. Gestation varies from 40 to 75 days with an average of 51 days. Like most other members of the weasel family, mink exhibit delayed implantation; the embryos do not implant and begin completing their development until approximately 30 days before birth. The single annual litter of about 3 to 6 young is born in late April or early May and their eyes open at about 3 weeks of age. The young are born in a den which may be a bank burrow, a muskrat house, a hole under a log, or a rock crevice. The mink family stays together until late summer when the young disperse. Mink become sexually mature at about 10 months of age.

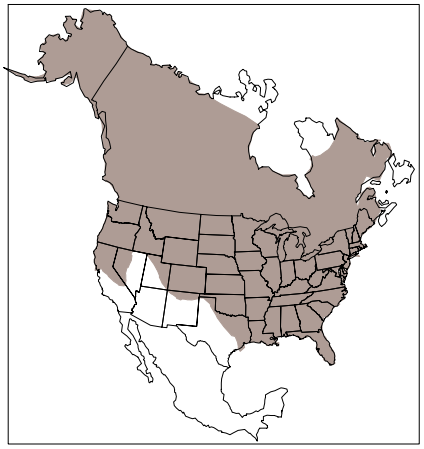

Fig. 2. Distribution of mink in North America.

Mink are active mainly at night and are active year-round, except for brief intervals during periods of low temperature or heavy snow. Then they may hole up in a den for a day or more. Male mink have large home ranges and travel widely, sometimes covering many miles (km) of shoreline. Females have smaller ranges and tend to be relatively sedentary during the breeding season.

Damage and Damage Identification

Mink may occasionally kill domestic poultry around farms. They typically kill their prey by biting them through the skull or neck. Closely spaced pairs of canine tooth marks are sign of a mink kill.

Mink will attack animals up to the size of a chicken, duck, rabbit, or muskrat. While eating muskrats, a mink will often make an opening in the back or side of the neck and skin the animal by pulling the head and body through the hole as it feeds. Like some other members of the weasel family, mink occasionally exhibit "surplus killing" behavior (killing much more than they can possibly eat) when presented with an abundance of food, such as in a poultry house full of chickens. Mink may place many dead chickens neatly in a pile. Mink can eat significant numbers of upland nesting waterfowl or game bird young, particularly in areas where nesting habitat is limited.

Legal Status

In California, mink are designated as furbearing mammals.

See California statutes and regulations regarding the take of furbearing and nongame mammals.

Damage Prevention and Control Methods

Mink damage usually is localized. If needed, lethal controls can be directed at the individual mink causing the damage.

Exclusion

Usually the best solution to mink predation on domestic animals is to physically exclude their entry, sealing all openings larger than 1 inch (2.5 cm) with wood or tin and by using 1-inch (2.5-cm) mesh poultry netting around chicken yards and over ventilation openings. Mink do not gnaw like rodents, but they are able to use burrows or gnawed openings made by rats.

Habitat Modification

Habitat modification generally is not a feasible means of reducing mink predation problems on farms. If the objective is to increase natural production of upland nesting wild birds, however, habitat modification may be applicable. The best method of increasing upland nesting success is usually to increase the size and quality of cover areas such as grasslands, legumes, or set-aside areas. Although increasing the density of nesting cover may reduce nest predation by mink, it could lead to an increase in nest predation by species which favor dense cover, such as the Franklin ground squirrel. Because mink frequently use multiple den sites, elimination of potential denning areas may reduce their densities.

Frightening

There are no known frightening devices that are effective for deterring mink predation.

Trapping

Body-gripping traps are illegal for use in commercial fur or recreational application in California (see regulations).

There are zones throughout California where the use of Conibear-type traps and snares, except those totally submerged, and deadfall traps are prohibited for the protection of the San Joaquin kit fox and Sierra Nevada red fox (see regulations).

In California, mink can most easily be captured in Conibear®-type body-gripping traps equivalent to No. 120 traps. Mink are suspicious of new objects and are difficult to capture in live traps. Single-door live traps may be effective if baited and placed in dirt banks or rock walls. Double-door live traps can be effective in runways, particularly if the trap doors are wired open and the trap is left in place for some time before activating the trap. Live traps may also be effective around farmyards because mink are more accustomed to encountering human-made objects in those areas.

Use live traps around a farmyard if there is a high likelihood of catching pets. Otherwise, Conibear® traps can be used with or without bait in runs or holes used by mink.

Shooting

Some states may have restrictions on shooting mink, although many will make exceptions in damage situations. If a mink is raiding poultry and can be caught in the act, shooting the animal is a quick way to solve the problem. Normally, though, it is difficult to shoot mink because of their nocturnal habits.

Economics of Damage and Control

Although an individual incident of mink predation can be costly, overall the problem is not very significant to agriculture. Mink damage control on a case-by-case basis generally can be justified from a cost/benefit standpoint, but large-scale control programs are neither necessary nor desirable. Exclusion procedures may or may not be economically justifiable, depending on the severity of the problem and the amount of repairs needed. Normally, such costs can be justified for a recurring problem when amortized over the life of the exclusion structures. Usually damage from other predators and rodents is reduced as well.

Mink are important semiaquatic carnivores in wetland wildlife communities, and are also valuable as a fur resource. About 400,000 to 700,000 wild mink are harvested each year throughout North America, for an annual income exceeding $5 million. Therefore, all lethal control should be limited to specific instances of documented damage.

Acknowledgments

Information for this section came from a variety of published and unpublished sources. Information on damage identification was adapted from Dolbeer et al. (1994).

Figures 1 and 2 from Schwartz and Schwartz (1981).

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Editors

Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

James E. Miller
Program Leader, Fish and Wildlife
USDA Extension Service
Natural Resources and Rural
Development Unit
Washington, DC 20250

MUSKRATS

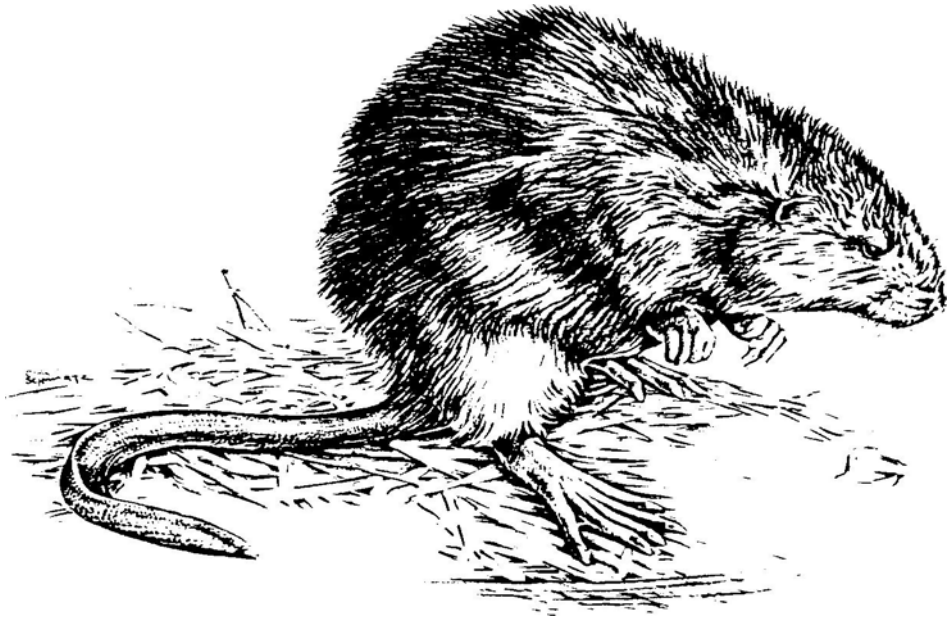

Fig. 1. Muskrat, *Ondatra zibethicus*

Damage Prevention and Control Methods

Exclusion

Riprap the inside of a pond dam face with rock, or slightly overbuild the dam to certain specifications.

Cultural Methods and Habitat Modification

Eliminate aquatic vegetation as a food source.

Draw down farm ponds during the winter months.

Frightening

Seldom effective in controlling serious damage problems.

Repellents

None are registered.

Trapping

Body-gripping traps are illegal for use in commercial fur or recreational application in California (see regulations).

There are zones throughout California where the use of Conibear-type traps and snares, except those totally submerged, and deadfall traps are prohibited for the protection of the San Joaquin kit fox and Sierra Nevada red fox (see regulations).

Shooting

Effective in eliminating some individuals.

Other Methods

Integrated pest management.

Identification

The muskrat (*Ondatra zibethicus,* Fig. 1) is the largest microtine rodent in the United States. It spends its life in aquatic habitats and is well adapted for swimming. Its large hind feet are partially webbed, stiff hairs align the toes (Fig. 2), and its laterally flattened tail is almost as long as its body. The muskrat has a stocky appearance, with small eyes and very short, rounded ears. Its front feet, which are much smaller than its hind feet, are adapted primarily for digging and feeding.

The overall length of adult muskrats is usually from 18 to 24 inches (46 to 61 cm). Large males, however, will sometimes be more than 30 inches (76 cm) long, 10 to 12 inches (25 to 31 cm) of which is the laterally flattened tail. The average weight of adult muskrats is

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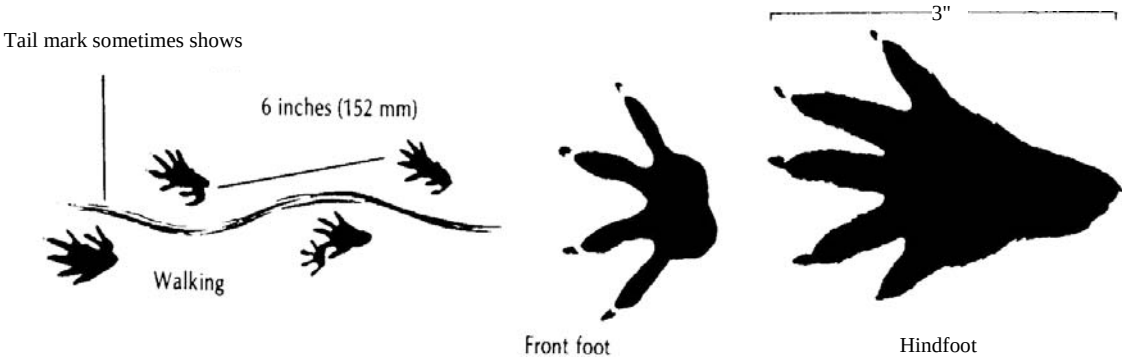

Fig. 2. Muskrat tracks

from 1 1/2 pounds (0.7 kg) to over 4 pounds (1.8 kg), with most at about 2 1/2 pounds (1.1 kg). The color of the belly fur is generally light gray to silver to tan, and the remaining fur varies from dark tan to reddish brown, dark brown, and black.

The name *muskrat,* common throughout the animal's range, derives from the paired perineal musk glands found beneath the skin at the ventral base of the tail in both sexes. These musk glands are used during the breeding season. Musk is secreted on logs or other defecation areas, around houses, bank dens, and trails on the bank to mark the area.

The muskrat has an upper and a lower pair of large, unrooted incisor teeth that are continually sharpened against each other and are well designed for gnawing and cutting vegetation. It has a valvular mouth, which allows the lips to close behind the incisors and enables the muskrat to gnaw while submerged. With its tail used as a rudder and its partially webbed hind feet propelling it in the water, the muskrat can swim up to slightly faster than 3 miles per hour (4.8 kph). When feeding, the muskrat often swims backward to move to a more choice spot and can stay underwater for as long as 20 minutes. Muskrat activity is predominantly nocturnal and crespuscular, but occasional activity may be observed during the day.

Muskrats in the wild have been known to live as long as 4 years, although most do not reach this age. In good habitat and with little competition, muskrats are very prolific. With a gestation period of between 25 and 30 days, females in the southern part of the range commonly produce 5 to 6 litters per year.

Range

The range of the muskrat extends from near the Arctic Circle in the Yukon and the Northwest Territories, down to the Gulf of Mexico, and from the Aleutians east to Labrador and down the Atlantic coast into Georgia (Fig. 3). The muskrat has been introduced practically all over the world, and, like most exotics, has sometimes caused severe damage as well as ecological problems. Muskrats often cause problems with ponds, levees, and crop culture, whether introduced or native. Muskrats are found in most aquatic habitats throughout the United States and Canada in streams, ponds, wetlands, swamps, drainage ditches, and lakes.

Fig. 3. Range of the muskrat in North America.

Habitat

Muskrats can live almost any place where water and food are available year-round. This includes streams, ponds, lakes, marshes, canals, roadside ditches, swamps, beaver ponds, mine pits, and other wetland areas. In shallow water areas with plentiful vegetation, they use plant materials to construct houses, generally conical in shape (Fig. 4). Elsewhere, they prefer bank dens, and in many habitats, they construct both bank dens and houses of vegetation. Both the houses of vegetation and the bank burrows or dens have several underwater entrances via "runs" or trails. Muskrats often have feeding houses, platforms, and chambers that are somewhat smaller than houses used for dens.

Burrowing activity is the source of the greatest damage caused by muskrats in much of the United States. They damage pond dams, floating styrofoam marinas, docks and boathouses, and lake shorelines. In states where rice and aquaculture operations are big business, muskrats can cause extensive economic losses. They damage rice culture by burrowing through or into levees as well as by eating substantial amounts of rice and cutting it down for building houses. In waterfowl marshes, population irruptions can cause "eat-out" where aquatic

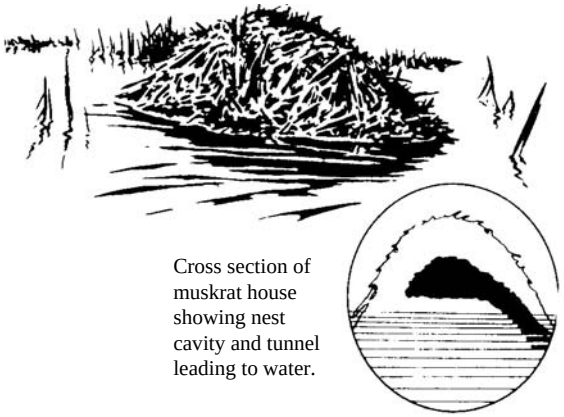

Fig. 4. Muskrat house

vegetation in large areas is virtually eliminated by muskrats. In some locations, such as in the rice-growing areas of Arkansas, muskrats move from overwintering habitat in canals, drainage ditches, reservoirs, and streams to make their summer homes nearby in flooded rice fields. In aquaculture reservoirs, damage is primarily to levees or pond banks, caused by burrowing.

Food Habits

Muskrats are primarily herbivores. They will eat almost any aquatic vegetation as well as some field crops grown adjacent to suitable habitat. Some of the preferred natural foods include cattail, pickerelweed, bulrush, smartweed, duck potato, horsetail, water lily, sedges, young willow regeneration, and other aquatics. Crops that are occasionally damaged include corn, soybeans, wheat, oats, grain sorghum, and sugarcane. Rice grown as a flooded crop is a common muskrat food. It is not uncommon, however, to see muskrats subsisting primarily on upland vegetation such as bermuda grass, clover, johnsongrass, and orchard grass where planted or growing on or around farm pond dams.

Although primarily herbivores, muskrats will also feed on crayfish, mussels, turtles, frogs, and fish in ponds where vegetation is scarce. In some aquaculture industry areas, this feeding habit should be studied, as it may differ significantly from normal feeding activity and can cause economic loss.

General Biology, Reproduction, and Behavior

Muskrats generally have a small home range but are rather territorial, and during breeding seasons some dispersals are common. The apparent intent of those leaving their range is to establish new breeding territories. Dispersal of males, along with young that are just reaching sexual maturity, seems to begin in the spring. Dispersal is also associated with population densities and population cycles. These population cycles vary from 5 years in some parts of North America to 10 years in others. Population levels can be impacted by food availability and accessibility.

Both male and female muskrats become more aggressive during the breeding season to defend their territories. Copulation usually takes place while submerged. The young generally are born between 25 and 30 days later in a house or bank den, where they are cared for chiefly by the female. In the southern states, some females may have as many as 6 litters per year. Litters may contain as many as 15, but generally average between 4 and 8 young. It has been reported that 2 to 3 litters per female per year is average in the Great Plains. This capability affords the potential for a prolific production of young. Young may be produced any month of the year. In Arkansas, the peak breeding periods are during November and March. Most of the young, however, are produced from October until April. Some are produced in the summer and early fall months, but not as many as in winter months. The period of highest productivity reported for the Great Plains is late April through early May. In the northern parts of its range, usually only 2 litters per year are produced between March and September.

Young muskrats are especially vulnerable to predation by owls, hawks, raccoons, mink, foxes, coyotes, and — in the southern states — even largemouth bass and snapping turtles. The young are also occasionally killed by adult muskrats. Adult muskrats may also be subject to predation, but rarely in numbers that would significantly alter populations. Predation cannot be depended upon to solve damage problems caused by muskrats.

Muskrats are hosts to large numbers of endo- and ectoparasites and serve as carriers for a number of diseases, including tularemia, hemorrhagic diseases, leptospirosis, ringworm disease, and pseudotuberculosis. Most common ectoparasites are mites and ticks. Endoparasites are predominantly trematodes, nematodes, and cestodes.

Damage and Damage Identification

Damage caused by muskrats is primarily due to their burrowing activity. Burrowing may not be readily evident until serious damage has occurred. One way to observe early burrowing in farm ponds or reservoirs is to walk along the edge of the dam or shorelines when the water is clear and look for "runs" or trails from just below the normal water surface to as deep as 3 feet (91 cm). If no burrow entrances are observed, look for droppings along the bank or on logs or structures a muskrat can easily climb upon. If the pond can be drawn down from 1 1/2 to 3 feet (46 to 91 cm) each winter, muskrat burrows will be exposed, just as they would during extended drought periods. Any burrows found in the dam should be filled, tamped in, and covered with rock to avoid possible washout or, if livestock are using

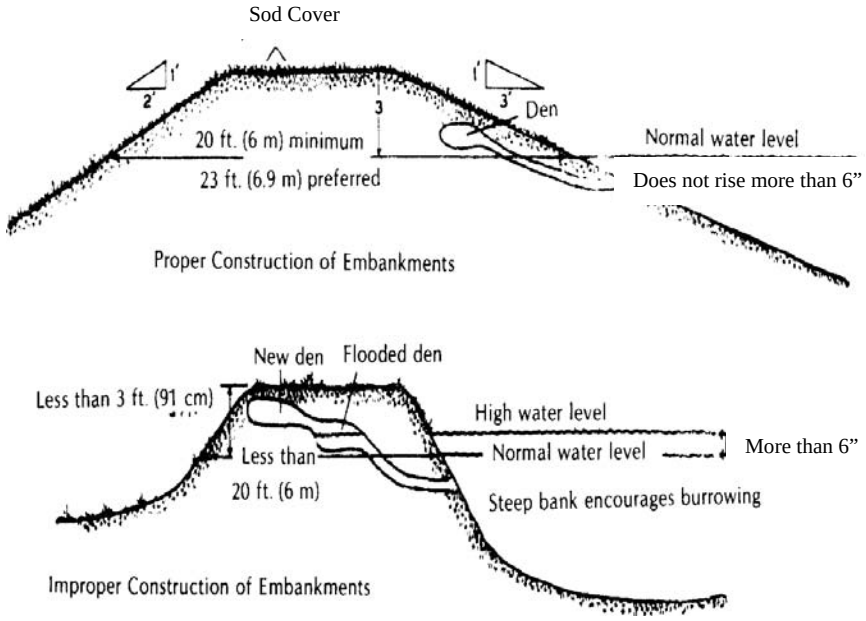

Fig. 5. Proper dam construction can reduce muskrat damage to the structure.

the pond, to prevent injury to a foot or leg.

Where damage is occurring to a crop, plant cutting is generally evident. In aquaculture reservoirs generally maintained without lush aquatic vegetation, muskrat runs and burrows or remains of mussels, crayfish, or fish along with other muskrat signs (tracks or droppings) are generally easy to observe.

Legal Status

Muskrats nationwide for many years were known as the most valuable furbearing mammal — not in price per pelt, but in total numbers taken. In California, muskrats are designated as furbearing mammals.

See California statutes and regulations regarding the take of furbearing and nongame mammals.

Damage Prevention and Control Methods

Exclusion

Muskrats in some situations can be excluded or prevented from digging into farm pond dams through stone rip-rapping of the dam. Serious damage often can be prevented, if anticipated, by constructing dams to the following specifications: the inside face of the dam should be built at a 3 to 1 slope; the outer face of the dam at a 2 to 1 slope with a top width of not less than 8 feet (2.4 m), preferably 10 to 12 feet (3 to 3.6 m). The normal water level in the pond should be at least 3 feet (91 cm) below the top of the dam and the spillway should be wide enough that heavy rainfalls will not increase the level of the water for any length of time (Fig. 5). These specifications are often referred to as overbuilding, but they will generally prevent serious damage from burrowing muskrats. Other methods of exclusion can include the use of fencing in certain situations where muskrats may be leaving a pond or lake to cut valuable garden plants or crops.

Cultural Methods and Habitat Modification

The best ways to modify habitat are to eliminate aquatic or other suitable foods eaten by muskrats, and where possible, to construct farm pond dams to previously suggested specifications. If farm pond dams or levees are being damaged, one of the ways that damage can be reduced is to draw the pond down at least 2 feet (61 cm) below normal levels during the winter. Then fill dens, burrows, and runs and rip-rap the dam with stone. Once the water is drawn down, trap or otherwise remove all muskrats.

Frightening Devices

Gunfire will frighten muskrats, especially those that get hit, but it is not effective in scaring the animals away from occupied habitat. No conventional frightening devices are effective.

Repellents

No repellents currently are registered for muskrats, and none are known to be effective, practical, and environmentally safe.

Fig. 7. Conibear®-type body-gripping kill trap

Fumigants
No fumigants are currently registered for muskrat control.

Trapping

Body-gripping traps are illegal for use in commercial fur or recreational application in California (see regulations).

There are zones throughout California where the use of Conibear-type traps and snares, except those totally submerged, and deadfall traps are prohibited for the protection of the San Joaquin kit fox and Sierra Nevada red fox (see regulations).

There have probably been more traps sold for cat catching muskrats than for catching any other furbearing species. A number of innovative traps have been constructed for both live trapping and killing muskrats, such as barrel, and stovetop traps.

The most effective and commonly used type of traps for muskrats in California is the Conibear®-type No. 110 (Fig. 7) The Conibear®-type, No. 110 is a preferred choice because it is as effective in 6 inches (15 cm) of water as at any deeper level. It kills the muskrat almost instantly, thus preventing escapes. All that is needed to make this set is a trap stake and trap.

As a test of trap efficiency, this author once set 36 Conibear®-type No. 110 traps in a 100-acre (40-ha) rice field. The next day 34 muskrats were removed. The remaining traps had not been tripped. Obviously, the area held high populations of muskrats and had not been subjected to recent control efforts. Results were 93.3% effectiveness with the Conibear®-type and 100% catch per traps tripped.

The most effective sets are those placed in "runs" or trails where the muskrat's hind feet scour out a path into the bottom from repeated trips into and out of the den. These runs or trails can be seen in clear water, or can be felt underwater with hands or feet. Which runs are being used and which are alternate entrances can usually be discerned by the compaction of the bottom of the run. Place the trap as close to the den entrance as possible without restricting trap movement.

Trapping muskrats during the winter furbearer season can be an enjoyable past-time and even profitable where prices for pelts range from $2.00 to $8.00 each. Price differences depend on whether pelts are sold "in the round" or skinned and stretched. Many people supplement their income by trapping, and muskrats are one of the prime targets for most beginners learning to trap. Therefore, unless muskrats are causing serious damage, they should be managed like other wildlife species to provide a sustained annual yield. Unfortunately, when fur prices for muskrats are down to less than $2.00 each, interest in trapping for fur seems to decline. However, in damage situations, it may be feasible to supplement fur prices to keep populations in check.

Shooting

Where it can be done safely, shooting may eliminate one or two individuals in a small farm pond. Concentrated efforts must be made at dusk and during the first hours of light in the early morning. Muskrats shot in the water rarely can be saved for the pelt and/or meat.

Other Methods

Although a variety of other methods are often employed in trying to control muskrat damage, a combination of trapping and proper use of toxicants is the most effective means in most situations. In situations where more extensive damage is occurring, it may be useful to employ an integrated pest management approach: (1) modify the habitat by removing available food (vegetation); (2) concentrate efforts to reduce the breeding population during winter months while muskrats are concentrated in overwintering habitat; and (3) use both registered toxicants and trapping in combination with the above methods.

Economics of Damage and Control

Assessment of the amount of damage being caused and the cost of prevention and control measures should be made before undertaking a control program. Sometimes this can be easily done by the landowner or manager through visual inspection and knowledge of crop value or potential loss and reconstruction or replacement costs. Other situations are more difficult to assess. For example, what is the economic value of frustration and loss of a truckload of minnows and/or fish after a truck has fallen through the levee into burrowed-out muskrat dens? Or how do you evaluate the loss of a farm pond dam or levee and water behind it from an aquaculture operation where hundreds of thousands of pounds of fish are being grown? Rice farmers in the mid-South or in California must often pump extra, costly irrigation water and shovel levees every day because of muskrat damage. The expense of trapping or other control measures may prove cost-effective if damage is anticipated.

Obviously, the assessments are different in each case. The estimate of economic loss and repair costs, for example, for rebuilding levees, replacing drain pipes, and other measures, must be compared to the estimated cost of prevention and/or control efforts.

Economic loss to muskrat damage can be very high in some areas, particularly in rice and aquaculture producing areas. In some states damage may be as much as $1 million per year. Totals in four states (Arkansas, California, Louisiana, and Mississippi) exceed losses throughout the rest of the nation.

Elsewhere, economic losses because of muskrat damage may be rather limited and confined primarily to burrowing in farm pond dams. In such limited cases, the value of the muskrat population may outweigh the cost of the damage.

Muskrat meat has been commonly used for human consumption and in some areas called by names, such as "marsh rabbit." A valuable resource, it is delicious when properly taken care of in the field and in the kitchen. Many wild game or outdoor cookbooks have one or more recipes devoted to "marsh rabbit." Care should be taken in cleaning muskrats because of diseases mentioned earlier.

Muskrat pelts processed annually are valued in the millions of dollars, even with low prices; thus the animal is certainly worthy of management consideration. It obviously has other values just by its place in the food chain.

Acknowledgments

Most of the information in this chapter was obtained from experience gained in Alabama, where as a youngster I trapped muskrats and other furbearers to sell, and in Arkansas where muskrat control is a serious economic problem. Colleagues in the Arkansas Cooperative Extension Service, and especially county extension agents, provided the opportunity and background for obtaining this information. The Arkansas Farm Bureau, many rice farmers, fish farmers, and other private landowners/managers, as well as the Arkansas Game and Fish Commission and the Arkansas State Plant Board, were also important to the development of this information.

Figures 1 through 4 from Schwartz and Schwartz (1981).

Figure 5 from Henderson (1980).
Figure 7 from Miller (1976).

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